

**Chassahowitzka River
Recommended Minimum
Flows and Levels
November 2010 Draft
Prepared
Pursuant to 373.042 F.S.**

Southwest Florida
Water Management District



Photo: W. Sotera

Chassahowitzka River System Recommended Minimum Flows and Levels

November 2010
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Acknowledgements

We would like to thank several of our colleagues at the Southwest Florida Water Management District for their contributions and useful suggestions concerning the work summarized in this report. In particular, we would like to acknowledge Ron Basso for estimating anthropogenic impacts to flow in the Chassahowitzka system and Doug Leeper for contributing significantly to Chapter 3 and providing an insightful review of the report. We are also indebted to District staff who conducted field sampling for the project (Don Hampton, Courtney James, Tammy Hinkle, Jason Hood and Richard Gant) and to Barbara Matrone for her assistance in document production. Sid Flannery provided historical datasets and valuable knowledge about prior District projects related to the Chassahowitzka River.

Finally, we would like to thank the many District contractors that contributed to this report. Dynamic Solutions LLC contributed the hydrodynamic modeling utilizing bathymetry data provided by Dr. Ping Wang of the University of South Florida (USF). Ernst Peebles with his staff and students at USF, and Tim MacDonald and his colleagues at Florida Fish and Wildlife Conservation Commission collected and analyzed the fish and invertebrate data. Ernie Estevez of Mote Marine Lab conducted the mollusk surveys and Ernie and Jay Leverone collected benthic samples for enumeration and analysis in addition to enumerating the macrophyte community. Additional analysis of the benthic results was completed by the staff at Janicki Environmental, Inc.

Using results from the individuals and organizations identified above, the staff of Balanced Environmental Management Systems (BEM), Inc., including Ken Duffy, Jay Burrell and Kevin Zhu, in particular, completed the bulk of the analyses and much of the writing for this report. The cost of non-District support for the project was approximately \$509,380, which was provided by the Coastal Rivers Basin Board and the District Governing Board.

Conversion Table		
Metric to U.S. Customary		
Multiply	By	To Obtain
cubic meters per second (m ³ /s)	35.31	cubic feet per second (cfs)
cubic meters per second (m ³ /s)	23	million gallons per day (mgd)
millimeters (mm)	0.03937	inches (in)
centimeter (cm)	0.3937	inches (in)
meters (m)	3.281	feet (feet)
kilometers (km)	0.6214	statute miles (mi)
square meters (m ²)	10.76	square feet (feet ²)
square kilometers (km ²)	0.3861	square miles (square miles)
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m ³)	35.315	cubic feet (feet ³)
cubic meters (m ³)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
Celsius degrees (°C)	1.8*(°C) + 32	Fahrenheit (°F)
U.S. Customary to Metric		
Multiply	By	To Obtain
inches (in)	25.40	millimeters (mm)
inches (in)	2.54	centimeters (cm)
feet (feet)	0.3048	meters (m)
statute miles (mi)	1.609	kilometers (km)
square feet (feet ²)	0.0929	square meters (m ²)
square miles (square miles)	2.590	square kilometers (km ²)
acres	0.4047	hectares (ha)
gallons (gal)	3.785	liters (l)
cubic feet (feet ³)	0.02831	cubic meters (m ³)
acre-feet	1233.0	cubic meters (m ³)
Fahrenheit (°F)	0.5556*(°F-32)	Celsius degrees (°C)
U.S. Customary to U.S. Customary		
Multiply	By	To Obtain
acre	43560	square feet (feet ²)
square miles (square miles)	640	acres
cubic feet per second (cfs)	0.646	million gallons per day (mgd)

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Executive Summary

The headwaters for the Chassahowitzka River are formed by the Chassahowitzka Main Spring. More than a dozen springs discharge additional flow into the Chassahowitzka River from the Floridan aquifer. For the purpose of minimum flows development and implementation, the Chassahowitzka River and associated springs are collectively considered to be the Chassahowitzka River system. The river receives a small amount of surface runoff from its 89 square miles watershed, but the overwhelming majority of flow arises from the 180 square miles springshed which produces a discharge that varies little with season. The river flows 5.6 miles (9 km) from the headspring to the Gulf of Mexico at Chassahowitzka Bay. It is designated an "Outstanding Florida Water" and the lower half of the river is part of the more than 31,000-acre Chassahowitzka National Wildlife Refuge.

Salinity in the Chassahowitzka River system may vary from fresh to brackish at the headwater and increases substantially as water moves through the marsh and into the estuary, mixing with more saline Gulf of Mexico water. The river transitions from salt marsh at the river's mouth to freshwater forested wetland approximately 3.1 miles (5 km) upstream from the river mouth.

Spring discharge is the primary freshwater source into the Chassahowitzka River system. However, continuous records are only available for the Chassahowitzka Main Spring. Flows from the spring are monitored by the United States Geological Survey (USGS). The discharge record begins in 1997 and stage begins in 1999. Spring discharge was estimated for periods preceding the initiation of USGS discharge measurement based on a regression equation developed for river flows and water levels in the Floridan Aquifer. The median flow of the Chassahowitzka River based on estimated and measured flows for the baseline period (1967-2007) used for determination of the minimum flows recommended in this report was 63 cubic feet per second (cfs).

There are currently no surface water withdrawals from the Chassahowitzka River currently permitted by the District. Groundwater withdrawals may, however, reduce discharge from the springs that contribute to the river's flow. A regional surface water/groundwater integrated model was used to determine that estimated water use in the region for 2005 resulted in a 0.7 cfs reduction in flows. For purposes of minimum flows development, this impact was considered insignificant and the evaluation proceeded without correction or modification of the reference period discharge record.

A variety of ecological resources of concern were identified and evaluated for response to reduced flows using both numeric models and empirical regressions. Resources of concern included submersed aquatic vegetation, benthic macroinvertebrates, molluscs, planktonic and nektonic fish and invertebrates, salinity-based habitat, and thermal refuge habitat for manatees during critically cold periods. Break-points in ecological response were not observed, and a fifteen percent loss of resource was adopted as representing significant harm.

The MFL recommendation is based on the resource most sensitive to reduced flow. Twenty-nine responses were evaluated, of which twenty-one were incorporated into development of the minimum flow for the Chassahowitzka River system. The two most restrictive components evaluated were the acute thermal refuge and the fish/invertebrate

community. In both cases, an 11-12 percent reduction in baseline flow results in a 15 percent loss of volumetric thermal refuge for the West Indian manatee and a 15 percent loss of abundance (median value for seven taxa) of juvenile fish. Therefore, it is recommended that the minimum flow for the Chassahowitzka River system (including all contributing springs and associated creeks) be maintained at 89 percent of the baseline flow. In the absence of locally measured flows, the Chassahowitzka River System MFL shall also apply to Blind Springs.

CHAPTER 1 - PURPOSE & BACKGROUND OF MFL

1.1 Overview and Legislative Direction

The Southwest Florida Water Management District (District or SWFWMD), by virtue of its responsibility to permit the consumptive use of water and a legislative mandate to protect water resources from “significant harm”, has been directed to establish minimum flows and levels (MFLs) for streams and rivers within its boundaries (Section 373.042, Florida Statutes; hereafter abbreviated as F.S.). As currently defined by statute, **“the minimum flow for a given watercourse shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.”** Minimum flows and levels are established and used by the District for water resource planning, as one of the criteria used for evaluating water use permit applications, and for the design, construction and operation of surface water management systems.

Development of a minimum flow or level does not in itself protect a water body from significant harm; however, resource protection, recovery and regulatory compliance can be supported once the flow or level standards are established. State law governing implementation of minimum flows and levels (Section 373.0421, F.S.) requires development of a recovery or prevention strategy for water bodies if the “existing flow or level in a water body is below, or is projected to fall within 20 years below, the applicable minimum flow or level”. Recovery or prevention strategies are developed to: “(a) achieve recovery to the established minimum flow or level as soon as practicable; or (b) prevent the existing flow or level from falling below the established minimum flow or level.” Periodic re-evaluation and as necessary, revision of established minimum flows and levels are also required by state law.

According to state law, minimum flows and levels are to be established based upon the best information available (Section 373.042, F.S), with consideration of “...changes and structural alterations to watersheds, surface waters and aquifers and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer...” (Section 373.0421, F.S.). Changes, alterations and constraints associated with water withdrawals are not to be considered when developing minimum flows and levels. However, according to the State Water Resource Implementation Rule (Chapter 62-40.473, Florida Administrative Code; hereafter abbreviated as F.A.C.), “...consideration shall be given to the protection of water resources, natural seasonal fluctuations in water flows or levels, and environmental values associated with coastal, estuarine, aquatic and wetlands ecology, including:

- 1) Recreation in and on the water;
- 2) Fish and wildlife habitats and the passage of fish;
- 3) Estuarine resources;
- 4) Transfer of detrital material;
- 5) Maintenance of freshwater storage and supply;
- 6) Aesthetic and scenic attributes;
- 7) Filtration and absorption of nutrients and other pollutants;

- 8) Sediment loads;
- 9) Water quality; and
- 10) Navigation.”

The Water Resource Implementation Rule also indicates that "minimum flows and levels should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary to establish the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area".

The District has developed specific methodologies for establishing minimum flows or levels for lakes, wetlands, rivers and aquifers, subjected the methodologies to independent, scientific peer-review, and in some cases, incorporated the methods into its Water Level and Rates of Flow Rule (Chapter 40D-8, F.A.C.). Components of recovery strategies needed to restore minimum flows and levels that are not currently being met have been incorporated into the District's Recovery and Prevention Strategies for Minimum Flows and Levels Rule (Chapter 40D-80, F.A.C.)

Because minimum flows are used for long-range planning and since the setting of minimum flows can potentially impact (restrict) the use and allocation of water, establishment of minimum flows will not go unnoticed or unchallenged. The science upon which a minimum flow is based, the assumptions made, and the policy used must therefore be clearly defined as each minimum flow is developed.

1.2 Historical Perspective

For freshwater streams and rivers, the development of instream flow legislation can be traced to the work of fisheries biologists. Major advances in instream flow methods have been rather recent, dating back not much more than 35 to 40 years. A survey completed in 1986 (Reiser et al., 1989) indicated that at that time only 15 states had legislation explicitly recognizing that fish and other aquatic resources required a certain level of instream flow for their protection. Nine of the 15 states were western states "where the concept for and impetus behind the preservation of instream flows for fish and wildlife had its origins" (Reiser et al., 1989). Stalnaker et al. (1995) have summarized the minimum flows approach as one of standards development, stating that, "[f]ollowing the large reservoir and water development era of the mid-twentieth century in North America, resource agencies became concerned over the loss of many miles of riverine fish and wildlife resources in the arid western United States. Consequently, several western states began issuing rules for protecting existing stream resources from future depletions caused by accelerated water development. Many assessment methods appeared during the 1960's and early 1970's. These techniques were based on hydrologic analysis of the water supply and hydraulic considerations of critical stream channel segments, coupled with empirical observations of habitat quality and an understanding of riverine fish ecology... Application of these methods usually resulted in a single threshold or 'minimum' flow value for a specified stream reach."

1.3 The Flow Regime

The idea that a single minimum flow is not satisfactory for maintaining a river ecosystem was most emphatically stated by Stalnaker (1995) who declared that “minimum flow is a myth.” The purpose of his paper was to argue that “multiple flow regimes are needed to maintain biotic and abiotic resources within a river ecosystem” (Hill et al. 1991). The logic is that “maintenance of stream ecosystems rests on streamflow management practices that protect physical processes which, in turn, influence biological systems.” Hill et al. (1991) identified four types of flows that should be considered when examining river flow requirements, including:

- 1) flood flows that determine the boundaries of and shape floodplain and valley features;
- 2) overbank flows that maintain riparian habitats;
- 3) in-channel flows that keep immediate streambanks and channels functioning; and
- 4) in-stream flows that meet critical fish requirements.

As emphasized by Hill et al. (1991), minimum flows methodologies should involve more than a consideration of immediate fish needs or the absolute minimum required to sustain a particular species or population of animals, and should take into consideration “how streamflows affect channels, transport sediments, and influence vegetation.” Although not always appreciated, it should also be noted “that the full range of natural intra- and inter-annual variation of hydrologic regimes is necessary to [fully] sustain the native biodiversity” (Richter et al. 1996). Successful completion of the life-cycle of many aquatic species is dependent upon a range of flows, and alterations to the flow regime may negatively impact these organisms as a result of changes in physical, chemical and biological factors associated with particular flow conditions.

Recently, South African researchers, as cited by Postel and Richter (2003), listed eight general principles for managing river flows:

- 1) "A modified flow regime should mimic the natural one, so that the natural timing of different kinds of flows is preserved.
- 2) A river's natural perenniality or non-perenniality should be retained.
- 3) Most water should be harvested from a river during wet months; little should be taken during the dry months.
- 4) The seasonal pattern of higher baseflows in wet season should be retained.
- 5) Floods should be present during the natural wet season.
- 6) The duration of floods could be shortened, but within limits.
- 7) It is better to retain certain floods at full magnitude and to eliminate others entirely than to preserve all or most floods at diminished levels.
- 8) The first flood (or one of the first) of the wet season should be fully retained."

Common to this list and the flow requirements identified by Hill et al. (1991) is the recognition that in-stream flows and out of bank flows are important and that seasonal variability of flows should be maintained. Based on these concepts, the preconception that minimum flows (and levels) are a single value or the absolute minimum required to maintain ecologic health in most systems has been abandoned in recognition of the important ecologic and hydrologic functions of streams and rivers that are maintained by different ranges of flow. And while the term “minimum flows” is still used, the concept has evolved to one that recognizes the need to maintain a “minimum flow regime.”

In Florida, for example, the Water Resource Implementation Rule indicates that "minimum flows and levels should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary to establish the limit beyond which further withdrawals would be significantly harmful to the water resources or the ecology of the area" (Rule 624-40.473(2), F.A.C.). The St. Johns River Water Management District typically develops multiple flows requirements when establishing MFLs (Chapter 40C-8, F.A.C.) and for the Wekiva River noted that, "[s]etting multiple minimum levels and flows, rather than a single minimum level and flow, recognizes that lotic [running water] systems are inherently dynamic" (Hupalo et al. 1994).

General information pertaining to the establishment of minimum flows and levels in the District is available from the District's Minimum Flows and Levels (Environmental Flows) web page at: <http://www.swfwmd.state.fl.us/projects/mfl/>. Specific information regarding methods used to establish minimum flows and levels and established minimum flows and level is available at the District's Minimum Flows and Levels (Environmental Flows) Documents and Reports page at:

http://www.swfwmd.state.fl.us/projects/mfl/mfl_reports.html. An alternate approach which also maintains a flow regime is to develop MFLs using a "percentage of flow" as discussed in Flannery et al. (2002) and has been incorporated into several District surface water use permits. Often, the percentage of flow approach is superimposed on seasons known as 'Blocks'. However, the discharge from spring dominated systems such as the Chassahowitzka, flow does not always exhibit strong seasonal patterns and a single percentage reduction of baseline flow is appropriate.

1.4 Ecosystem Integrity and Significant Harm

Richter *et al.* (1996) note that "[a] goal of ecosystem management is to sustain ecosystem integrity by protecting native biodiversity and the ecological (and evolutionary) processes that create and maintain that diversity. Faced with the complexity inherent in natural systems, achieving that goal will require that resource managers explicitly describe desired ecosystem structure, function, and variability; characterize differences between current and desired conditions; define ecologically meaningful and measurable indicators that can mark progress toward ecosystem management and restoration goals; and incorporate adaptive strategies into resource management plans." Although it is clear that multiple flows are needed to maintain the ecological systems that encompass streams, riparian zones and valleys, much of the fundamental research needed to quantify the ecological links between the instream and out of bank resources, because of expense and complexity, remains to be done. This research is needed to develop more refined methodologies, and will require a multi-disciplinary approach involving hydrologists, geomorphologists, aquatic and terrestrial biologists, and botanists (Hill et al. 1991).

To justify adoption of a minimum flow for purposes of maintaining ecologic integrity, it is necessary to demonstrate with site-specific information the ecological effects associated with flow alterations and to also identify thresholds for determining whether these effects constitute significant harm. As described in Florida's legislative requirement to develop minimum flows, the minimum flow is to prevent "significant harm" to the state's rivers and streams. Not only must "significant harm" be defined so that it can be measured, it is also implicit that some deviation from the purely natural or existing long-term hydrologic

regime may occur before significant harm occurs. The goal of a minimum flow would not be to preserve a hydrologic regime without modification, but rather to establish the threshold(s) at which modifications to the regime begin to affect the aquatic resource and at what level significant harm occurs.

1.4.1 Defining Significant Harm

The goal of establishing minimum flows and levels is to protect water resources from significant harm due to withdrawals and was broadly defined in the enacting legislation as “the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.” What constitutes “significant harm” was not defined. The District has identified loss of flows associated with fish passage and maximization of stream bottom habitat with the least amount of flow as significantly harmful to river ecosystems. Also, based upon consideration of a recommendation of the peer review panel for the upper Peace River MFLs (Gore et al. 2002), significant harm in many cases can be defined as quantifiable reductions in habitat.

Ideally, there will be a clear “break point” that identifies significant harm. Unfortunately, more often in nature there is simply a monotonic continuum with a changing rate of response, but one that does not provide an easily identifiable break-point. Little guidance concerning identification of generally applicable thresholds associated with changes in flows or levels is found in the primary or secondary scientific and resource management literature and the definition of “significant harm” often becomes a policy decision rather than a technical decision.

In their peer review report on the upper Peace River, Gore et al. (2002) stated, “[i]n general, instream flow analysts consider a loss of more than 15 percent habitat, as compared to undisturbed or current conditions, to be a significant impact on that population or assemblage.” This recommendation was made in consideration of employing the Physical Habitat Simulation Model (PHABSIM) for analyzing flow, water depth and substrate preferences that define aquatic species habitats. With some exceptions (e.g., loss of fish passage or wetted perimeter inflection point), there are few “bright lines” which can be relied upon to judge when “significant harm” occurs. Rather loss of habitat in many cases occurs incrementally as flows decline, often without a clear inflection point or threshold.

Based on the comments of Gore et al. (2002) regarding significant impacts of habitat loss, a 15 percent change in habitat availability as a measure of significant harm for the purpose of MFLs development is recommended. Although a 15 percent change in habitat availability is recommended as a measure of unacceptable loss, it is important to note that percentage changes employed for other instream flow determinations have ranged from 10 percent to 33 percent. For example, Dunbar et al. (1998) in reference to the use of PHABSIM noted, “an alternative approach is to select the flow giving 80 percent habitat exceedance percentile,” which is equivalent to a 20 percent decrease. Jowett (1993) used a guideline of one-third loss (i.e., retention of two-thirds) of existing habitat at naturally occurring low flows, but acknowledged that, “[n]o methodology exists for the selection of a percentage loss of ‘natural’ habitat which would be considered acceptable.” Using optimization modeling techniques, the state of Texas set the MFL for Matagorda Bay based on a harvest constraint that no individual species would be less than eighty percent of historical average. An additional constraint was imposed that the

optimal solution falls between the 10th and 50th percentiles of historical flows (Powell et al. 2002).

1.4.2 Minimum Evaluation Criteria

Relating inherently variable biological responses to MFL objectives will ultimately require setting criteria for taking management action based on the strength of the biological response to flows or levels. The science of establishing MFLs is evolving and many researchers have turned to regression statistics to determine the statistical strength between biological responses and inflows. The most common measure of the strength is the correlation coefficient (r) which ranges from 0.0 to +1.0 for a response that increases with increasing flow. Conversely, r can range from 0.0 to -1.0 for a response that decreases with flow. The absolute value of the correlation coefficient provides information on the strength of the modeled relationship between two variables, with larger values indicating a stronger relationship. Another statistic, the coefficient of determination (r^2) is also convenient for flow-based regression analyses, because it reflects the fraction of the response variable that is attributable to changes in flow. It must, however, be recognized that a statistically significant relationship may still be of limited value for resource management. Taking an example from fish monitoring, it is often possible to develop statistically significant relationships that relate the number of animals to flow, but coefficient of determination values for these relationships may typically be very low, on the order of 0.1. This means that while there may be a significant relationship between the number of fish and flow, flow accounts for only 10 percent of the change in numbers. The remaining 90 percent of variation in fish abundance in this example is due to residual variation in flow and to another factor (or factors) other than flow. The management question then becomes "How much weight do we place on this relationship? Should we set flow limits when the majority of response is due to something other than flow?"

A similar problem facing the decision-makers is: "*How much data do we need?*" Taken in the context of establishing statistical relationships between flow and ecological resources the analogous question is: "*How many data points should I have to develop my regression equation?*" Research has shown that as the strength of the relationship diminishes, the number of observations required increases (so called "effect size").

It often becomes necessary to try to develop relationships between flow and some response with considerably fewer observations than recommended or desirable. While the legislature has indicated that an MFL should be based on the "best information available", at some point it becomes questionable whether a management decision should be based on a very low number of observations or a very low correlation, and it becomes preferable to establish acceptance criteria *a priori*. The criteria for a regression suitable for management decisions were proposed by Heyl (2008) in the development of the Weeki Wachee MFL. The same criteria have been applied to development of the Chassahowitzka River MFL. Namely, there must be a minimum of ten observations for each parameter in the regression, the regression must exhibit an r^2 of at least 0.30 and the underlying assumptions about regressions must be met.

1.5 Summary of the DISTRICT Approach for Developing Minimum Flows

1.5.1 Elements of Minimum Flows

It should be noted that when work began on the Chassahowitzka MFL, it was intended that the report include an MFL determination for both the freshwater riverine and the downstream estuarine portions of the river. However, during field investigations, it became apparent that even the relatively fresh minor spring tributaries were under tidal influence and the techniques traditionally used by the District to set freshwater MFL criteria could not be applied in the Chassahowitzka. While the approaches and tools differ between these two evaluations, both share a common philosophical approach in attempting to establish a flow regime instead of a single threshold flow. In addition, both the riverine and the estuarine evaluations normally embody recommendations by Beecher (1990) who noted *"it is difficult [in most statutes] to either ascertain legislative intent or determine if a proposed instream flow regime would satisfy the legislative purpose."* According to Beecher (as cited by Stalnaker et al. 1995), an instream flow standard should include the following elements:

- 1) a goal (e.g., non-degradation or, for the District's purpose, protection from "significant harm");
- 2) identification of the resources of interest to be protected;
- 3) a unit of measure (e.g., flow in cubic feet per second, habitat in usable area, inundation to a specific elevation for a specified duration);
- 4) a benchmark period, and
- 5) a protection standard statistic.

The District's approach for minimum flows development incorporates the five elements listed by Beecher (1990). The goal of an MFL determination is to protect the resource from significant harm due to withdrawals and was broadly defined in the enacting legislation as "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." What constitutes "significant harm" was not defined. Impacts on the water resources or ecology are evaluated based on an identified subset of potential resources of interest. Ten potential resources were listed in Section 1.1. They are recreation in and on the water; fish and wildlife habitats and the passage of fish; estuarine resources; transfer of detrital material; maintenance of freshwater storage and supply; aesthetic and scenic attributes; filtration and absorption of nutrients and other pollutants; sediment loads; water quality; and navigation. The approach outlined in this report identifies specific resources of interest and identifies, when it is important seasonally to consider these resources.

Fundamental to the approach used for development of MFLs is the realization that a flow regime is necessary to protect the ecology of the river system. The initial step in this process requires an understanding of historic and current flow conditions to determine if current flows reflect past conditions. If this is the case, the development of MFLs becomes a question of what can be allowed in terms of withdrawals before significant harm occurs. If there have been changes to the flow regime of a river, these must be assessed to determine if significant harm has already occurred. If significant harm has already occurred, recovery is required by statute. For development of minimum flows for the Chassahowitzka River, a "reference" period from 1967 through 2007 was used.

Flows prior to 1997 were estimated from the Weeki Wachee well. For flows from 1997 to 2007, the values reported by the USGS National Water Information System were used. Typically, the maximum flows expressed in cubic feet per second (cfs) occur in September through November and the minimum flows occur in May through July. Of particular note is the constancy of the flow as evidenced by the ratio (1.1) of median September flows (67 cfs) to median flows in May (60 cfs) is very small in contrast to runoff-dominated rivers where orders of magnitude differences in monthly flows are the norm. Since the Chassahowitzka River exhibits no significant seasonal flow variation, the Districts' preferred approach using seasonal "Blocks" was not used for the development of MFLs in this system.

Because the entire length of the Chassahowitzka River is tidally influenced, the District was unable to conduct the normal suite of analyses used to establish a recommended minimum flow for freshwater river segment. As a result, the recommended minimum flows developed for the estuarine portion of the Chassahowitzka River system are assumed to be equally protective of non-tidal freshwater habitat.

1.5.2 Flows and Levels

Although somewhat semantic, there is a distinction between flows, levels and volumes that should be appreciated. All terms apply to the setting of "minimum flows" for flowing waters. The term "flow" may most legitimately equate to water velocity; which is typically measured by a flow meter. A certain velocity of water may be required to physically move particles heavier than water; for example, periodic higher velocities will transport sand and detritus from upstream to downstream; higher velocities will move gravel; and still higher velocities will move rubble or even boulders. Conversely, reduced flows as may be found downstream of flow obstructions, or as the result of change in geometry (e.g. sudden deepening or widening in the channel) serve as important deposition areas. Flows may also serve directly as a cue for some organisms; for example, certain fish species search out areas of specific flow for reproduction and may move against flow or into areas of reduced or low flow to spawn. Certain macroinvertebrates drift or release from stream substrates in response to changes in flow. This release and drift among other things allows for colonization of downstream areas. One group of macroinvertebrates, the caddis flies, spin nets in the stream to catch organisms and detritus carried downstream, and their success in gathering/filtering prey is at least partially a function of flow. Other aquatic species have specific morphologies that allow them to inhabit and exploit specialized niches located in flowing water; their bodies may be flattened (dorsally-ventrally compressed) to allow them to live under rocks or in crevices; they may have special holdfast structures such as hooks or even secrete a glue that allows them to attach to submerged objects.

In some cases, the water level or the elevation of the water above a certain point is the critical issue to dependent biota. For example, the wetland fringing a stream channel is dependent on a certain hydroperiod or seasonal pattern of inundation. On average, the associated wetland requires a certain level and frequency of inundation. Water level and the duration that it is maintained will determine to a large degree the types of vegetation that can occur in an area. Flow and volume are not the critical criteria that need to be met, but rather elevation or level.

1.6 Content of Remaining Chapters

In this chapter, we have summarized the requirements and rationale for developing MFLs in general and introduced the need for protection of the flow regime rather than protection of a single minimum flow. The remainder of this document considers the development of MFLs specific to the Chassahowitzka River, which is defined as the river reach from the head springs located in Citrus County, south of the town of Homosassa Springs, to the confluence with the Gulf of Mexico.

Chapters 2 through 5 are intended to be largely descriptive of the system. Not all of the material presented in these chapters was used in setting the MFL, but it is important to characterize the nature of the system under investigation. For example, watershed land-use cannot be reasonably managed as an MFL issue, but it is important to understand that highly urbanized systems generally offer less habitat than relatively pristine systems, and this may have a bearing on the outcome of the MFL.

Chapter 2 contains a short description of the entire river basin and springshed, the hydrogeologic setting, and considers historical and current river flows and the factors that have influenced the flow regimes. In Chapter 3, the focus changes to a description of the estuarine characteristics. Chapter 4 is devoted to water quality with a focus on salinity and its relationship with flow.

Biological resources are described in Chapter 5 along with quantifiable relationships to flow that have been developed for the MFL evaluation. Goals and specific MFL resource criteria are defined in Chapter 6, while Chapter 7 is devoted to application of evaluation tools to determine what minimum flow(s) achieve the criteria established in the prior chapter. Finally, Chapter 8 provides a definition of the Chassahowitzka MFL. Chapters 9 and 10 contain literature cited and appendices, respectively, for the prior chapters. Chapter 11 contains review comments and the District's responses.

With the exceptions noted, the British system of measurement units has been utilized in this report. This will promote consistency with other District reports and Governor Crist's *Plain Language Initiative*¹ that promotes a writing style easily understood by the public. The exceptions to the British system are river or shoreline distance (expressed in kilometer, km), volume (cubic meters, m³), river bottom area (square meter, m²), water depth (expressed in meters) and concentration (expressed as milligrams per liter, mg/l). A table of common conversions and abbreviations is provided preceding the Table of Contents.

¹. State initiative can be found at http://www.flgov.com/pl_home

CHAPTER 2 - WATERSHED CHARACTERISTICS – PHYSICAL AND HYDROLOGY

2.1 Watershed and Springshed

The Chassahowitzka River is a 9 km long² spring-fed river located in a region of the west coast of Florida (Figure 2-1) known as the Florida Springs Coast, which includes the coast extending from the Pithlachascotee River located north of Tampa Bay to the Waccasassa River area located south of the Suwannee River Basin (Wolfe 1990). The river originates in Citrus County and enters the Gulf of Mexico at Chassahowitzka Bay. It is designated an “Outstanding Florida Water” by the Florida Department of Environmental Protection (FDEP) and the lower half of the river is part of the 35,000+acre Chassahowitzka National Wildlife Refuge established in 1943. Mean depth is approximately 3.0 feet (Notestein et al. 2001). The upper reach of the Chassahowitzka is relatively narrow but broadens considerably (to 574 feet) downstream.

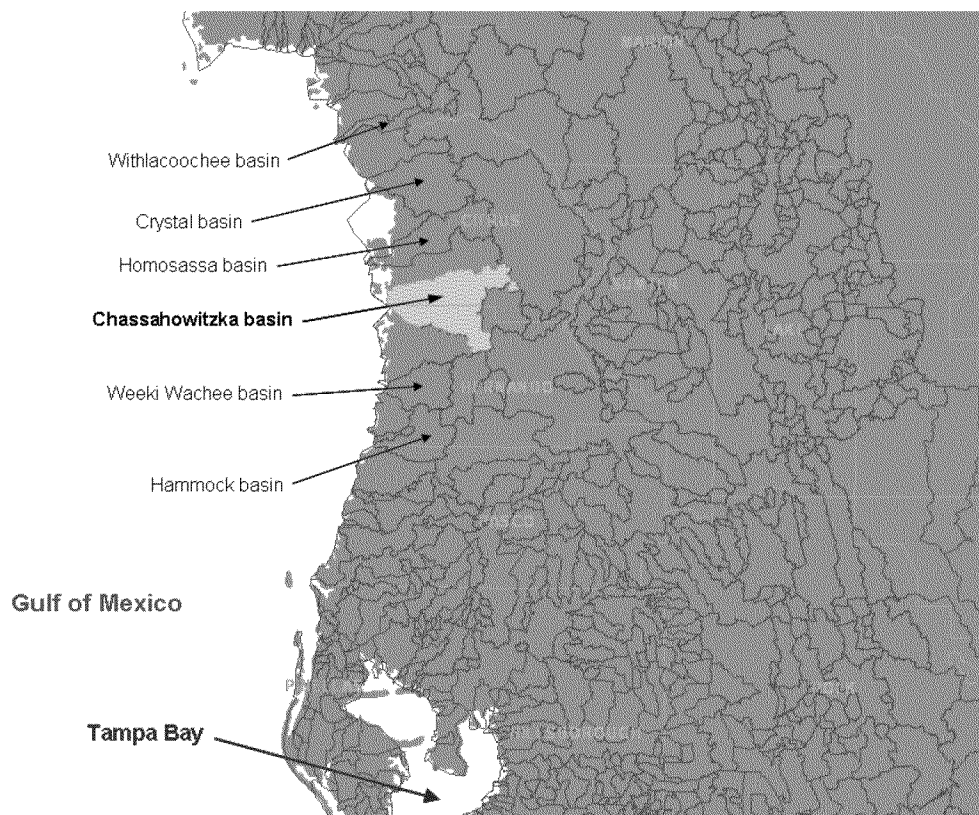


Figure 2-1 Florida Springs Coast Sub-basins including the Chassahowitzka Basin

². River kilometer (Rkm) measured from the seaward extent of the USGS drainage basin boundary at 28.6908 north latitude and 82.6432 west longitude. (See Figure 2-6).

The surface drainage area is approximately 89 square miles, but the springshed is significantly larger (Figure 2-2). Groundwater contribution is estimated to be from a 190 square miles area. Both the watershed and springshed are located in Citrus and Hernando Counties.

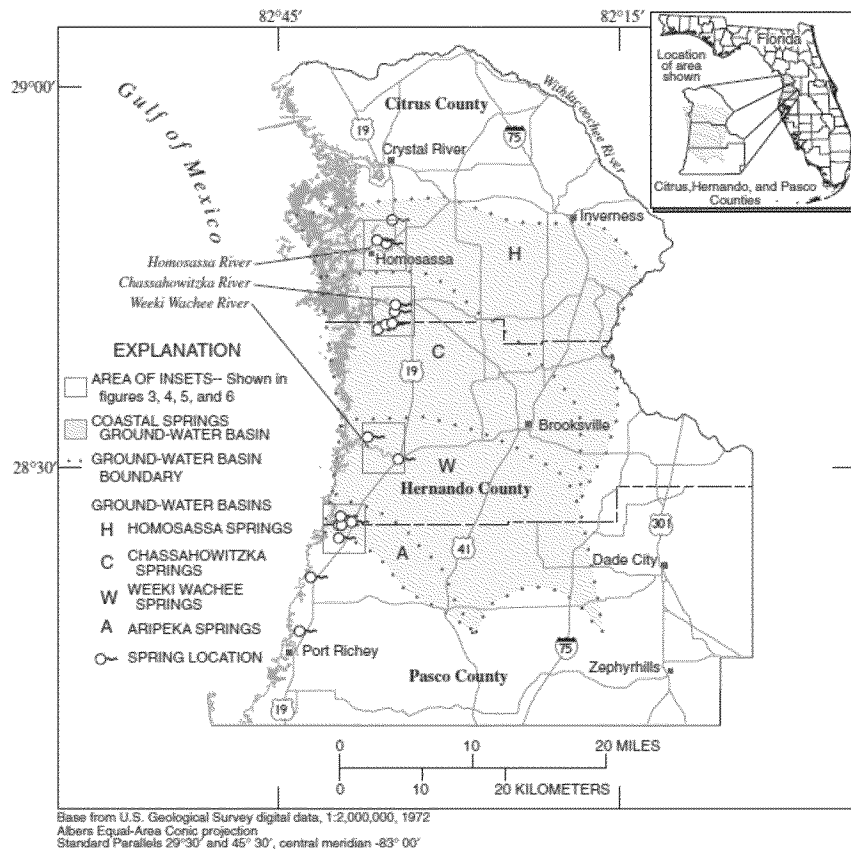


Figure 2-2 Chassahowitzka Springshed (Source:USGS Water Resources Investigation Report 01-4230)

The headwaters for the Chassahowitzka River are formed by the Chassahowitzka main spring, with Chassahowitzka Spring #1 located 350 feet upstream (Scott et al. 2004) of the main spring. Spring #1 marks the upper boundary of the study area for this MFL report. More than a dozen springs discharge additional flow into the Chassahowitzka River. The main spring is located about 200 feet northeast of the boat ramp at Citrus County Chassahowitzka River Campground (near the end of County Road 480), near the south side of a 50-foot wide canal that enters the spring pool from the east. Several springs flow into the main pool from the northeast. The main pool is nearly circular and about 150 feet in diameter. The bottom slopes gently toward the vent in a crevice about 25 feet long and 1 to 2 feet wide. In April 1962, the depth of the vent was 34.5 feet below water surface (Florida Geological Survey 2002). The Chassahowitzka is frequently listed (Scott et al. 2002. Wolfe 1990 and others) as a 1st magnitude spring (e.g., > 100 cfs), however that statement probably includes flow from Spring #1, Main and Crab as the daily average flows in the absence of Crab Spring have been on the order of 60 cfs

since the USGS began measurements downstream of the main spring (USGS 0230650) in 1997(See Section 2.3.1 for additional details.)

All the Chassahowitzka springs discharge water from the Floridan aquifer. Tides in the area are semidiurnal and unequal, generally ranging from 2.0 to 4.6 feet (Wolfe et al. 1990). Tidal water level fluctuations inversely affect discharges. In common with other streams along the Florida Springs Coast, the Chassahowitzka River flows over and drains a predominantly carbonate terrain, resulting in clear waters upstream and little or no sediment transport to the Gulf of Mexico at Chassahowitzka Bay (Wolfe et al. 1990). The lower river has a brown color from dissolved humics (Dixon and Estevez 2001) presumably derived from extensive marsh system which exists from river km 5.2 seaward (See Figure 3-8 in section 3.4).

2.1.1 Land Use/Land Cover

The 4 km (2.5 mi) of the Chassahowitzka River below the main spring are surrounded by a deciduous tidal freshwater floodplain forest, which ends at the boundary of the Chassahowitzka National Wildlife Refuge (Dixon and Estevez 2001). Cattail (*Typha* sp.) and reeds (*Phragmites* sp.) line some portions of shoreline in the upper river, with floating mats of senescent filamentous vegetation evident (Dixon and Estevez 2001). Terrestrial canopy cover shades only about three percent of the total river area, permitting submersed aquatic vegetation(SAV) to grow (Notestein et al. 2001). In the upper river, this includes the SAVs American eelgrass (*Vallisneria* sp.), pondweed (*Potamogeton* sp.), and some *Hydrilla verticillata* (Dixon and Estevez 2001). At the boundary of the Chassahowitzka National Wildlife Refuge, the riverbank vegetation is dominated by sawgrass (*Cladium jamaicensis*) and cattail (*Typha domingensis*); with cabbage palm (*Sabal palmetto*) hammocks and some black needlerush (*Juncus roemerianus*). Dixon and Estevez (2001) noted enteromorpha-like algae, Eurasian water milfoil (*Myriophyllum spicatum*), and *Hydrilla verticillata* as being very dense in 1996 but much reduced during a drought period in 2000. In the vicinity of Crawford Creek (Rkm 3.5) and Dog Island (Rkm 2.5), sawgrass and black needlerush line the shore, with some cattails present and *Ruppia maritima* (widgeon grass) occasionally present on the bottom (Dixon and Estevez 2001). In the lowermost portions of the river and in Chassahowitzka Bay, black needlerush is the dominant shore vegetation, with smooth cordgrass (*Spartina alterniflora*) occasionally present. Eastern oyster (*Crassostrea virginica*) forms bars in some areas and red mangrove (*Rhizophora mangle*) is also present to a limited extent. Seagrasses abound in Chassahowitzka Bay, in particular turtlegrass (*Thalassia testudinum*), shoalgrass (*Halodule wrightii*) and widgeon grass (Dixon and Estevez 2001). Table 2-1 provides the general land use and land cover for both the springshed and watershed.

The study area is nearly devoid of urbanization. There is little development along the Chassahowitzka River (See Figure 2-4 in section 2.3.1) The town of Chassahowitzka (a small residential community and fish camp) surrounds canals above spring #1 which have been dredged for residences. Faulty septic tanks are suspected of causing historical nutrient and bacterial contamination in the residential canals (Callahan et al. 2001); although recently the area has been converted to central sewer.³ However,

³. <http://citrusdaily.com/local-news/epa-grant-bringing-down-chassahowitzka-sewer-costs/2009/08/31/10599.html>

elevated nitrate continues to be problematic. Downstream development along the river is limited to approximately a dozen homes in the lower river, with only occasional boat docks and vacation houses at some locations. There are no direct surface water withdrawals from the Chassahowitzka River.

Table 2-1 Springshed and Watershed Land Use/Land Cover

Springshed Land Use/Land Cover - 2006		
Description	Percent	Acres
Disturbed Land	0	80
Mines	9	10,980
Non-forested Wetlands	3	4,066
Other Agricultural	14	16,478
Rangeland	1	1,371
Upland Forests	32	38,559
Urban	28	34,441
Water	1	1,297
Wetland Forests	12	14,678
Total	100	121,951

Watershed Land Use/Land Cover - 2006		
Description	Percent	Acres
Disturbed Land	0	22
Mines	4	2,538
Non-forested Wetlands	6	3,701
Other Agricultural	10	5,800
Rangeland	2	1,456
Upland Forests	39	22,715
Urban	21	12,403
Water	2	1,170
Wetland Forests	15	8,928
Total	100	58,734

2.2 Climate / Meteorology

The climate of the Springs Coast is mild and greatly influenced by the Gulf of Mexico. Mean daily summer high temperatures are in the low to mid 90s and the winter means are in the upper 50s with an annual average temperature of 70 °F. Annual precipitation averaged 55.8 inches at nearby Brooksville between 1904-2004 and is largely the result of localized convective thunderstorms during the summer (June through September) when 31.7 inches of accumulated rainfall is normal. However, unlike runoff-dominated rivers, this seasonal peak in rainfall does not translate into large differences in discharge (see 2.3.1 Discharge Estimates). Additional rain accompanies winter frontal systems, which result in a secondary peak in rainfall during February through April when another 9.8 inches of rainfall can be expected. These cold fronts result in an average of five freezing days per year (1892-2006), but can range up to 24 days (recorded in 1920).

The passage of strong winter cold fronts may cause extremes in tidal amplitude resulting in increased salinity throughout much of the river during high tide and exposure and

desiccation of submersed vegetation during the subsequent low tide. Summer cyclonic events may also result in similar water level extremes. Between 1910 and 2004, sixteen hurricanes passed within 75 statute miles of the Chassahowitzka River, at an average frequency of once every 6.25 years. Of particular note is the 27-year period with no hurricane activity, between Hurricane Gladys (10/1968) and Hurricane Erin (8/1995).

2.3 Flow and Hydrogeology (Adapted from Wolfe 1990, Knochenmus and Yobbi 2001)

Florida as it exists today is the emergent part of a peninsular platform that extends southward and separates the deep waters of the Atlantic from the deep waters of the Gulf of Mexico. Throughout the ages, portions of this platform have been episodically submerged and emergent, depending upon sea level. The limestone and dolomite bedrock that underlies the platform was deposited approximately 58 to 25 million years before present when the sea level was higher. The historical change in sea level gives rise to step-like terraces that progress from the shoreline to the interior.

The Chassahowitzka River lies within the Palimico terrace. This near-gulf terrace is part of a larger landform known as the Gulf Coastal Lowlands, which includes land from the Gulf of Mexico to an elevation of approximately 98 feet (30 m) above sea level.

The Springs Coast is a notable karst landscape, characterized by springs, sinkholes, and undulating topography. Karst features are a result of repeated chemical dissolution and deposition of the underlying carbonate rock (upper Floridan aquifer) in response to fluctuations in sea level over geologic time. The springs that contribute water flow to the Chassahowitzka River occur in the physiographic region designated as the Coastal Swamp (White 1970). This region is an area of upward flow from the Upper Floridan aquifer and active sinkhole formation is minimal (0-2 karst features per square mile). To the east, in the sand hills of the Gulf Coastal Lowlands, recharge conditions exist so the karst feature density is higher (10-25 solution features per square mile) and the well-drained soils support a unique scrub habitat (Wolfe 1990). Enlarged pores (vugs) in the carbonate rock tend to concentrate groundwater flow leading to additional dissolution and/or fractures. The result is a coastline that is dominated not by surface runoff, but by discharge of groundwater. Within the Springs Coast there are five 1st order (>100 cfs), eight 2nd order (10-100 cfs) and four 3rd order (<10 cfs) named springs.

2.3.1 Discharge Estimates

The District has contracted the USGS to install and maintain monitoring stations to collect water stage, temperature and conductivity data at a number of sites along the Florida Springs Coast (Table 2-2). Spring discharge is the primary freshwater source into the Chassahowitzka River system. However, continuous records are only available for the Chassahowitzka Main Spring. The flows are monitored by the USGS gauging station 02310650 (Figure 2-3). The daily discharge record begins in 1997 and stage begins in 1999. In addition to the identified springs, the Chassahowitzka River system receives discharge from smaller springs as well as receiving diffuse groundwater discharge. Figure 2-4 provides a location map of springs for the Chassahowitzka River System. The

centerline of the river with labeled river kilometers is also depicted. The Chassahowitzka River was measured from the seaward extent of the USGS drainage basin boundary (river kilometer 0⁴) to the upper reach of the river (river kilometer 9). Table 2-3 summarizes the average flows from five significant springs from 1988 to 1989 and average salinity of a number of samplings between 1993 and 1997 (Dynamic Solutions, LLC 2009). [See Table 2-5 for earlier measurements at these springs]

2.3.1.1 Discharge from USGS 02310650

It should be noted that prior to 1997, the sporadic discharges reported by the USGS for site 02310650 included contribution from Crab Creek as well as the Main Spring and contribution above the main spring, while the post 1997 discharge reported for this site does not include contribution from Crab Creek. (Personal communication. Dann Yobbi). A summary of discharge measurements which includes Crab Creek can be found in Table 3 of the USGS Water Resources Investigation (WRI) Report 88-4044 while the results of individual efforts to measure discharge can be found in the appendices of WRI report 92-4069 and WRI report 01-4230.

⁴ River kilometer zero (Rkm 0) is defined as the confluence of the river with the seaward extent of the USGS drainage basin. For the Chassahowitzka River, this is located at 28.6908 north latitude and 82.643 west longitude.

Table 2-2 Summary of USGS Gauges Near Chassahowitzka River

Sort	Site ID	Site Name	Location	History of Observations
1	02310650	CHASSAHOWITZKA RIVER NEAR HOMOSASSA FL		Daily data for Discharge (1997 ~ present), Water temperature (bottom, 2004 ~ present), Gage height (1999 ~ present), Specific conductance (2004 ~ present).
2	02310663	CHASSAHOWITZKA RIVER NEAR CHASSAHOWITZKA FL		Daily data for Discharge (2003 ~ present), Water temperature (bottom, 2004 ~ present), Gage height (1984 ~ present), Specific conductance (2003 ~ present).
3	02310673	CHASSAHOWITZKA R AT DOG ISL NR CHASSAHOWITZKA FL		Daily data for Water temperature (2005 ~ present), Gage height (2005 ~ present), Specific conductance (2005 ~ present).
4	02310674	CHASSAHOWITZKA R AT MOUTH NR CHASSAHOWITZKA FL		Daily data for Water temperature (2005 ~ present), Gage height (2005 ~ present), Specific conductance (2005 ~ present).
5	284152082375000	CHASSAHOWITZKA RIVER AT MOUTH NEAR CHASHWTZ FL		Daily data for Salinity (1984 - 1985).
6	284254082362310	CHASSAHOWITZKA R ABOVE JOHNSON CK NR CHASHWTZ FL		Daily data for Salinity (1984 - 1985).
7	284317082330601	CHASSAHOWITZKA WELL 1 NEAR CHASSAHOWITZKA FL		Daily data for Groundwater elevation (1965 ~ 2004); Grab data for: Water temperature, Specific conductance, Water quality.
8	284317082330602	CHASSAHOWITZKA WELL 2 NEAR CHASSAHOWITZKA FL		Grab data only: Groundwater elevation, Water temperature, Specific conductance, Water quality.



Figure 2-3 USGS Gauging Station 02310650 (Chassahowitzka near Homosassa)

**Table 2-3 Discharge information for several springs in the Chassahowitzka Group.
(Champion and Starks 2001)**

Spring Name	Average Discharge (cfs)
Crab Creek	48.7
Potter Creek	18.6
Baird Spring	5.6
Beteejay Head Spring	6.4
Blue Run	6.6

The Chassahowitzka Main Spring plus spring #1 is estimated to contribute 50 percent of the flow. Monthly mean flows of spring #1, Main and Crab spring have ranged from 31.8 to 197 cfs (mean=140 cfs; data from 1930-1972 cited in Yobbi and Knochnemus 1989). Frazer et al. (2001a) reported a mean flow of approximately 140 cfs during their three-year study. Flows measured at USGS Station 02310650 (spring #1 plus Main), from 1999 through 2005, ranged from 25 to 87 cfs, with a median flow of 59 cfs. Yobbi (1992) observed that there is a seasonal component to the spring's discharge. Lowest flows occur during June and July and the greatest flows occur during early fall, but the seasonal variation is small relative to runoff-fed river systems.

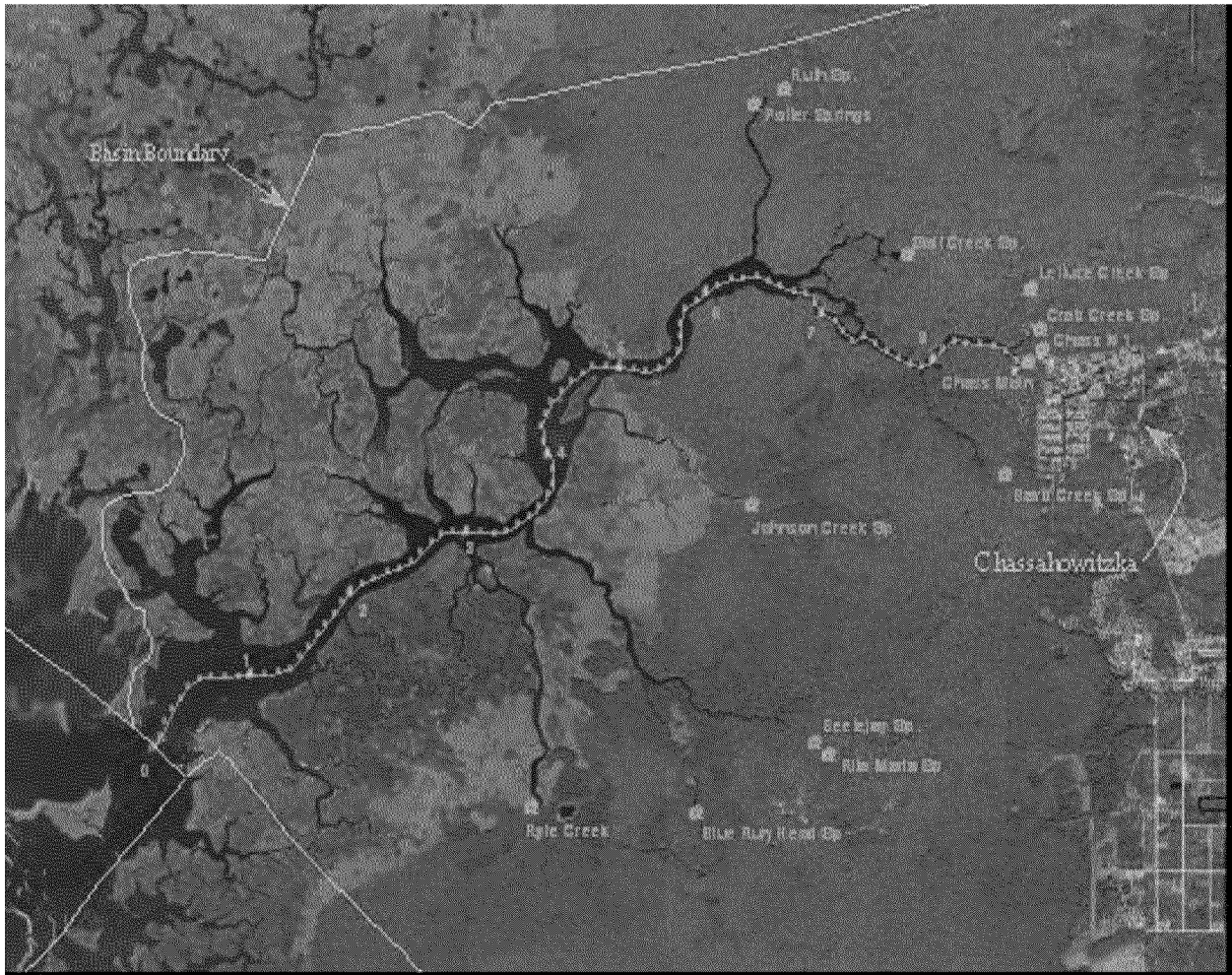


Figure 2-4 Location of Springs in the Chassahowitzka Group

As discussed above, the discharge record of the Chassahowitzka River, as measured at USGS Station 02310650, begins in February 1997. Flows in the Chassahowitzka River prior to February 20, 1997 can be estimated using the following regression equation of river flow with water levels from a nearby Floridan aquifer well – the Weeki Wachee well (283201082315601) (see Appendix 1. Heyl 2010):

$$Q_{est} = 12.428 + 2.924 \text{ WW_WL}; n = 3260, r^2 = 0.75$$

Where:

Q(est) is the estimated daily discharge in cfs at USGS Station 02310650

WW_WL is the water surface elevation of the Week Wachee Well in feet

n = number of paired measurements used for model development; and

r^2 = coefficient of determination for the regression.

Daily estimated and reported discharges (1967-2007) are summarized by month in Table 2-4, which provides select percentile values and portrayed in Figure 2-5 as a time series of mean monthly discharge. Typically, the maximum flows occur in September

(median 66.7 cfs) through November (65.5 cfs) and the minimum flows occur in May (59.9 cfs) through July (60.8 cfs). Of particular note is the constancy of the flow as evidenced by a narrow range of median flows in May and September (ratio = 1.1) in contrast to runoff dominated rivers where orders of magnitude differences in monthly flows are the norm. The overall median flow of the Chassahowitzka River for 1967-2007 is 63 cfs.

Table 2-4 Monthly percentile discharge (cfs) of Chassahowitzka River 1967-2007

Month	Percentile								
	1%	5%	10%	25%	50%	75%	90%	95%	99%
1	51.4	52.6	55.5	58.0	63.8	68.8	71.7	73.0	75.1
2	51.4	54.0	54.2	57.6	63.5	67.4	69.7	74.2	75.4
3	46.4	51.0	53.9	56.5	62.1	66.5	70.1	74.1	77.8
4	43.3	48.6	52.3	55.2	61.3	65.8	70.0	74.0	75.8
5	42.7	47.4	50.9	54.4	59.9	64.0	69.3	71.8	73.4
6	42.3	46.6	49.8	55.3	60.4	62.3	67.1	71.2	71.9
7	42.7	48.6	51.3	56.7	60.8	63.8	71.6	73.7	74.8
8	45.5	52.5	54.1	58.4	63.5	67.1	73.0	77.4	80.9
9	46.7	55.5	56.4	59.4	66.7	72.7	77.4	79.4	81.2
10	47.5	55.6	57.9	60.9	66.1	74.8	78.1	80.2	81.0
11	50.1	53.8	58.1	59.6	65.5	73.5	75.8	77.7	78.8
12	51.6	53.2	56.7	57.6	64.5	71.1	74.4	75.5	76.0

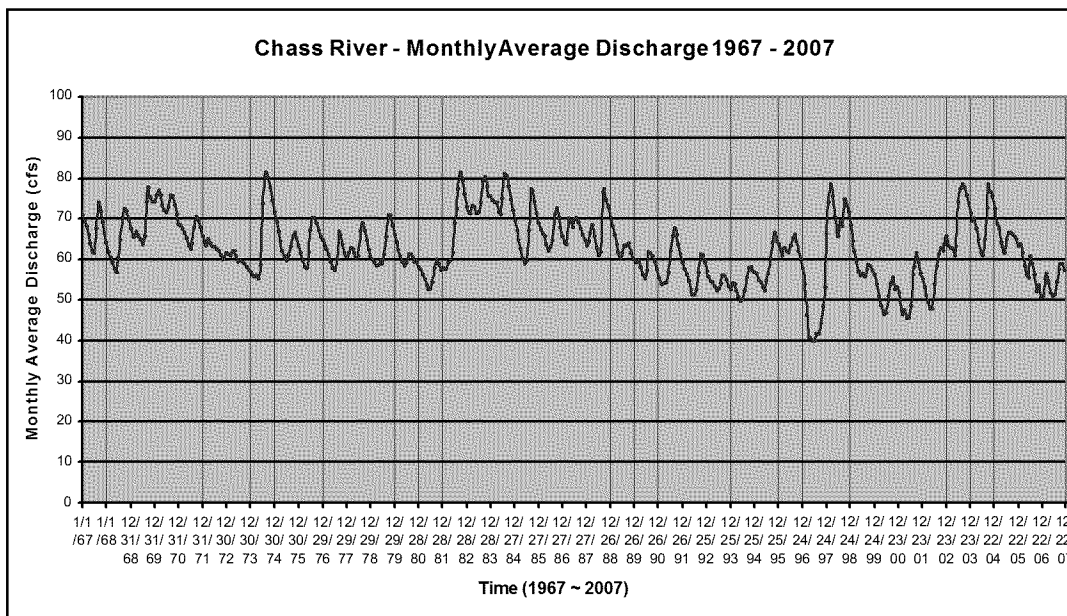


Figure 2-5 Mean monthly discharge (cfs) of Chassahowitzka River 1967-2007

2.3.2 Reference Period

For development of minimum flows for the Chassahowitzka River a “reference” period from 1967 through 2007 was used. Flows prior to 1997 were estimated from the Weeki Wachee well. For flows from 1997 to 2007, the values reported by the USGS National Water Information System were used. Figure 2-6 depicts the mean annual flow during this time.

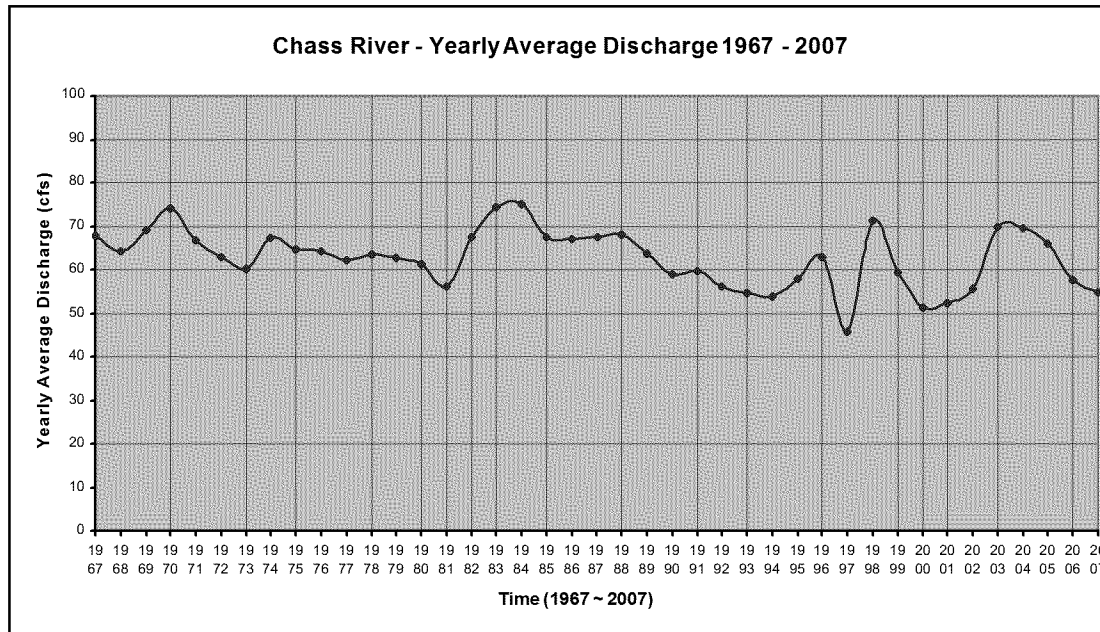


Figure 2-6 Mean annual flow (cfs) of Chassahowitzka River 1967 - 2007

2.4 Historical Change in Discharge

There are no surface water withdrawals from the Chassahowitzka River. However, groundwater withdrawals may indirectly affect the flow. A regional surface water/groundwater integrated model was used to evaluate the impact of groundwater pumpage on stream flow. The results indicate (See Appendix 2 - Basso 2008) that regional pumpage during 2005 caused an estimated 0.7 cfs decline on flows in the Chassahowitzka. For purposes of MFL development, this impact was considered insignificant and the evaluation proceeded without flow correction.

Based on the 1967-2007 composite discharge record (Figure 2.6), there has been a decline in annual average flow which is statistically significant (Kendall tau = -0.290, n= 41, p= 0.008). Regionally, the flow of many river system peaked in the mid-1960's, but comparison of the wet AMO period (Kelly 2004) covering 1940-1969 with the dry period (1970-1999) is not possible because the period of observations does not extent far enough in history. Nevertheless, in the absence of groundwater impacts, the decline is believed to be the result of climate and other natural conditions.

2.5 Ungauged Flow Estimates

It has long been recognized that the minor springs in the Chassahowitzka system collectively contribute a substantial amount of flow, but virtually all are tidally influenced and thus difficult to gauge. In addition to a changing hydraulic head, during flood tide much of the surrounding marsh is inundated. Separating these transient storage and head pressure changes from net discharge is difficult at best. Periodic measurements (Yobbi and Knochenmus 1989, Knochenmus and Yobbi 2001) have been made on most, but none exhibit a consistent discharge pattern as evidenced by the results in Table 2-5. In lieu of measuring the individual springs, a two sampling events were undertaken (VHB 2008a, 2008b) by D. Yobbi (USGS retired) to characterize the magnitude of these ungauged flow. Transects were established at Rkm 1.5 and Rkm 3.5 as shown in Figure 2-7.

Table 2-5 Spring discharge in Chassahowitzka system 1961-1972

Spring Discharge in Chassahowitzka System (Yobbi and Knochenmus 1989)					
Spring Identification	Name	Period of Observations	Number of Observations	Range (cfs)	Mean chloride (mg/l)
Unnamed spring No. 8	Bettjay group	1961	1	10	6,400
Unnamed spring No. 9	Bettjay group	1961 - 64	3	20.9 - 35.4	136
Unnamed spring No.10	Ryle Creek	1961	1	5	4,300
Unnamed spring No. 11	Blue Head	1961 - 64	2	5 - 26.2	3,800
Unnamed spring No. 12	Rita Marie	1961 - 65	6	9.1 - 39.9	2,110
Baird Creek	Baird Creek	1964 - 65	5	11.1 - 53.1	2,350
Chassahowitzka Spring	Chassahowitzka Spring	1930 - 72	81	31.8 - 197	127
Ruth Spring	Ruth Spring	1961 - 72	6	8.0 - 11.8	460
Potter Spring	Potter Spring	1961 - 65	6	0 - 22.0	460

Chass_contribQ.xls

The first sampling event took place between over a 4-hour period on January 10, 2008 and resulted in 32 discharge estimates at the upstream site and 18 estimates at the lower site. Over this period of observation, an increase of 90 cfs was measured. On March 27 these transects were monitored again over a 9 hour period with approximately 35 discharge measurements at each location. Regressions were established with USGS gauge 02310650 for various time lags. The investigators concluded :

Following review of the difference in discharge between the USGS site and the sampling transect sites; it is believe that ungaged seepage estimates below the USGS discharge site can be quantified on a limited basis using the field measurements and the regression equations. Differences in discharge and seepage estimates between the two transect sampling sites is highly dependent on river discharge above the transect sampling sites..... A better approach to quantifying discharge to the lower part of the Chassahowitzka River would be to measure individual spring runs below the

USGS discharge site on a quarterly basis (See Appendix 3 for original letter reports)

In lieu of additional discharge measurements of the individual spring runs, the District completed the MFL evaluation using the discharge estimates at the USGS 02310650 site.

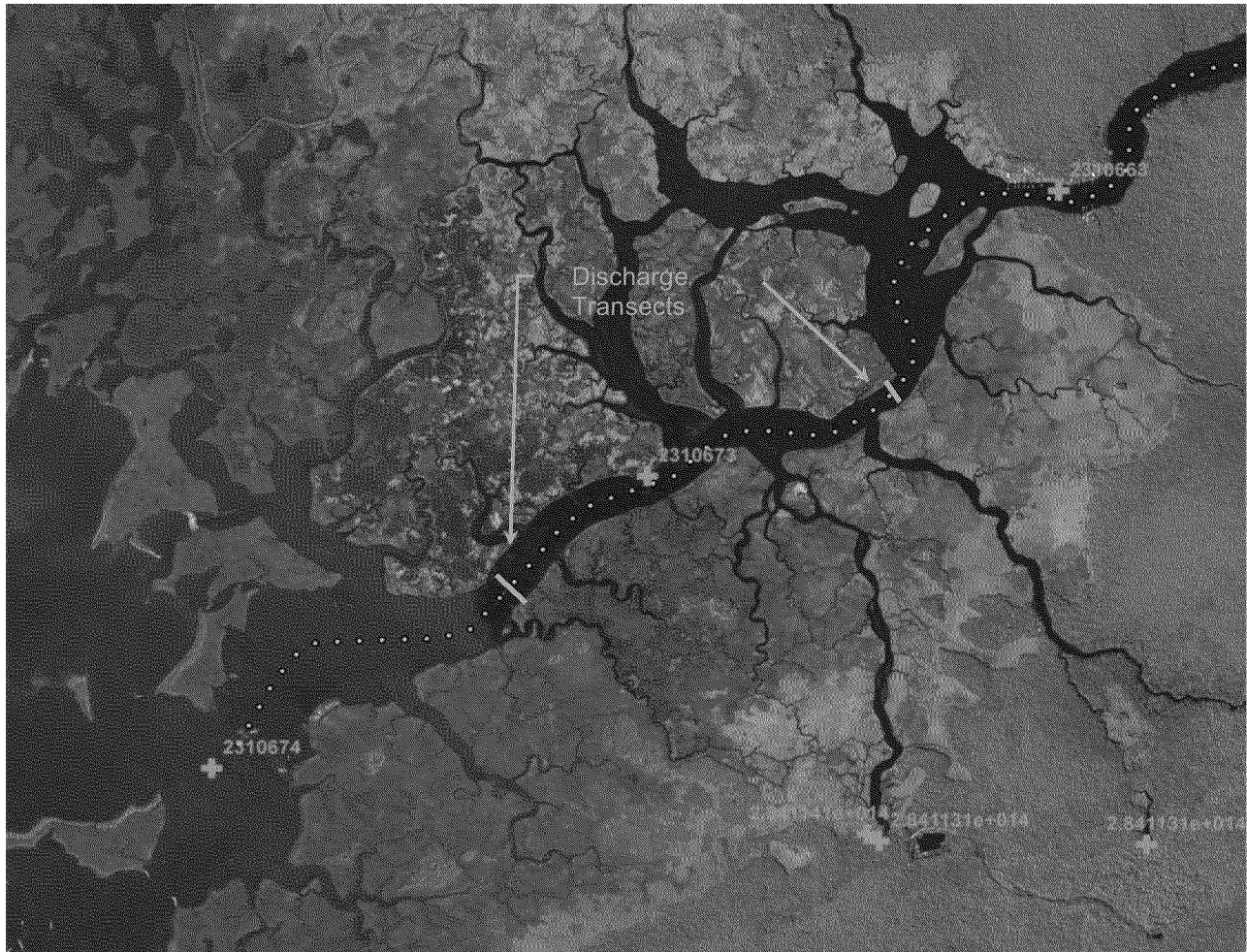


Figure 2-7 Location of discharge transects and USGS stations

CHAPTER 3 - ESTUARY CHARACTERISTICS

3.1 Physical

3.1.1 Linear

The Chassahowitzka River flows west approximately 2.5 miles from the main spring boil to the beginning of the associated coastal marsh complex, and then another 2.5+ miles to the Gulf of Mexico. The channel of the Chassahowitzka River is 50 to 200 feet wide and about 3 feet deep at its headwaters, and about 500 to 1200 feet wide and about 5 to 15 feet deep near the Gulf of Mexico. The river is tidally affected along its entire length (Yobbi and Knochenmus 1989). The majority of stream discharge emanates from a main spring boil; however, several smaller spring runs (Crab, Baird, and Potter creeks) in the upper river contribute additional flow. Tidal cycles influence both spring discharge and flow within the river (Yobbi 1992).

Surface waters in this stretch of the coast are also affected by several forcing functions (Wolfe 1990) not exerted on inland waters. Winds play a major role in setting up circulation on the shallow coast, resulting in a net long-term movement of coastal waters north and west during late spring, summer and early fall. In contrast, during the winter months a net circulation to the south and east results from the winds associated with passage of cold fronts. Short-term convective onshore/offshore forcing functions characterize the summer months.

3.1.2 Area / Volume (Adapted from Dynamic Solutions, LLC 2009)

The University of South Florida completed a bathymetric survey of the Chassahowitzka River System in 2007. Transects were collected at a maximum spacing of 492 feet (Figure 3-1). These data were referenced to North American Vertical Datum of 1988 (NAVD88), and were converted to mean tide level (MTL) by shifting the elevations +3.15 inches (the average NAVD88 minus MTL for the stations at the National Oceanic and Atmospheric stations at Clearwater (8726724) and Cedar Key (8727520)).

A digital terrain model (DTM) was produced from the University of South Florida transects and estimated depths derived from the measured data (Figure 3-2). The DTM used a 10 meter by 10 meter grid that allowed the scale assessments of the depth and volumes. River distances upstream from the Gulf of Mexico were provided by District as geographic information system (GIS) coverage and all data sources were normalized to this system. Cumulative and river segment area and volume estimates based on a mean tide water level are provided in Figure 3-3 and Table 3-1.

River area and volume values associated with approximate 0.5 km river segments and cumulative river reach values were determined using the digital terrain model and polygons that were based on a centerline segment GIS layer delineated in 100-m (328.1 feet) intervals (Figure 3-4).



Figure 3-1 Location of bathymetric survey transects.

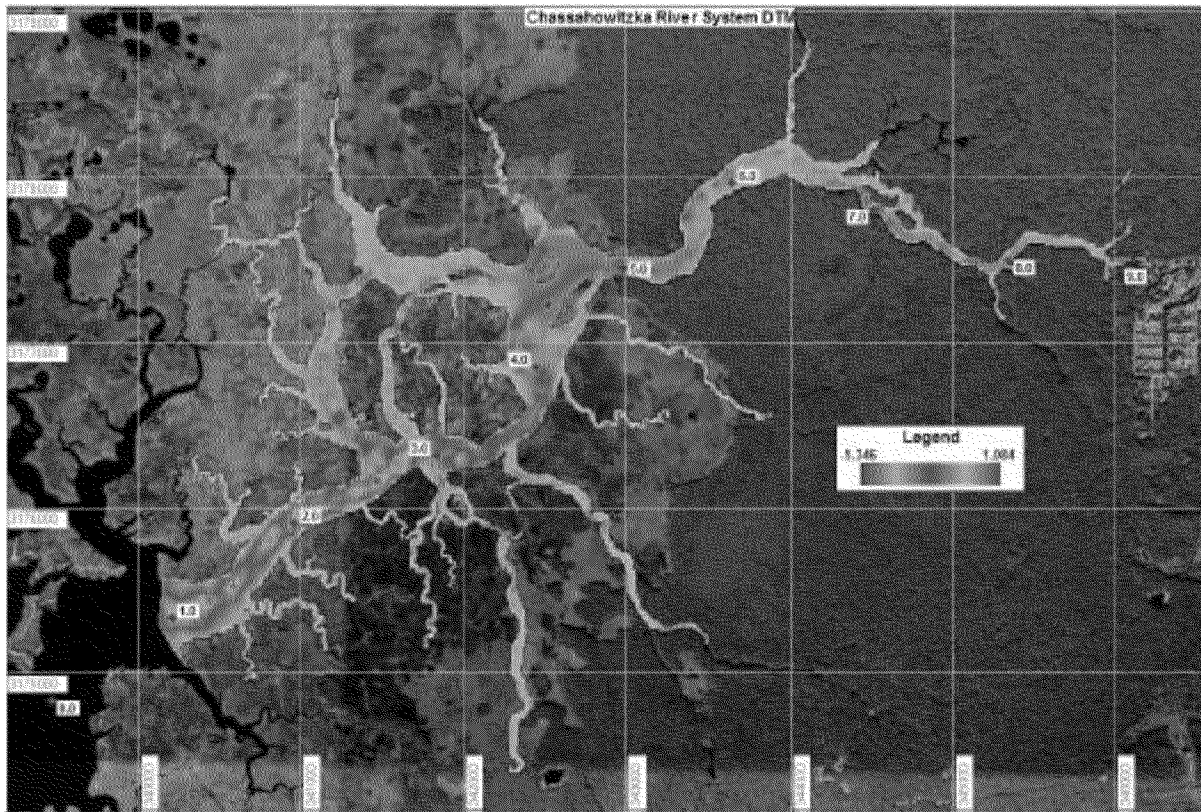


Figure 3-2 Digital terrain model of the Chassahowitzka River system with river kilometers indicated along the river centerline. The legend indicates depths in meters relative to mean tide water level and correspond to a range from -5.3 to +1.1 meters). Average system depth = 1.1 meters. Image reproduced from Dynamic Solutions, LLC (2009).

Bathymetric data presented in Table 3-1 were used to develop linear regressions for predicting cumulative upstream area, volume and shoreline lengths within the Chassahowitzka River for a mean tide water level (Dynamic Solutions, LLC 2009). Prediction of these morphometric parameters was necessary for modeling of salinity and biological responses used for determining minimum flow recommendations. The regressions took the following form:

$$\begin{aligned}
 \text{Area} &= -1522.2 \cdot \text{Rkm}^4 + 32925 \cdot \text{Rkm}^3 - 198581 \cdot \text{Rkm}^2 - 53880 \cdot \text{Rkm} + 2555100, \\
 &\quad \text{Adj-}r^2 = 0.993; \\
 \text{Volume} &= -1335 \cdot \text{Rkm}^4 + 26843 \cdot \text{Rkm}^3 - 131142 \cdot \text{Rkm}^2 - 340674 \cdot \text{Rkm} + 2879028, \\
 &\quad \text{Adj-}r^2 = 0.997; \\
 \text{Shoreline length} &= -0.115 \cdot \text{Rkm}^4 + 2.3117 \cdot \text{Rkm}^3 - 14.276 \cdot \text{Rkm}^2 + 17.645 \cdot \text{Rkm} + 66.915, \\
 &\quad \text{Adj-}r^2 = 0.988;
 \end{aligned}$$

where: Rkm is the river kilometer location between Rkm 0 and Rkm 9.6, and Adj- r^2 is the adjusted coefficient of determination for each model.

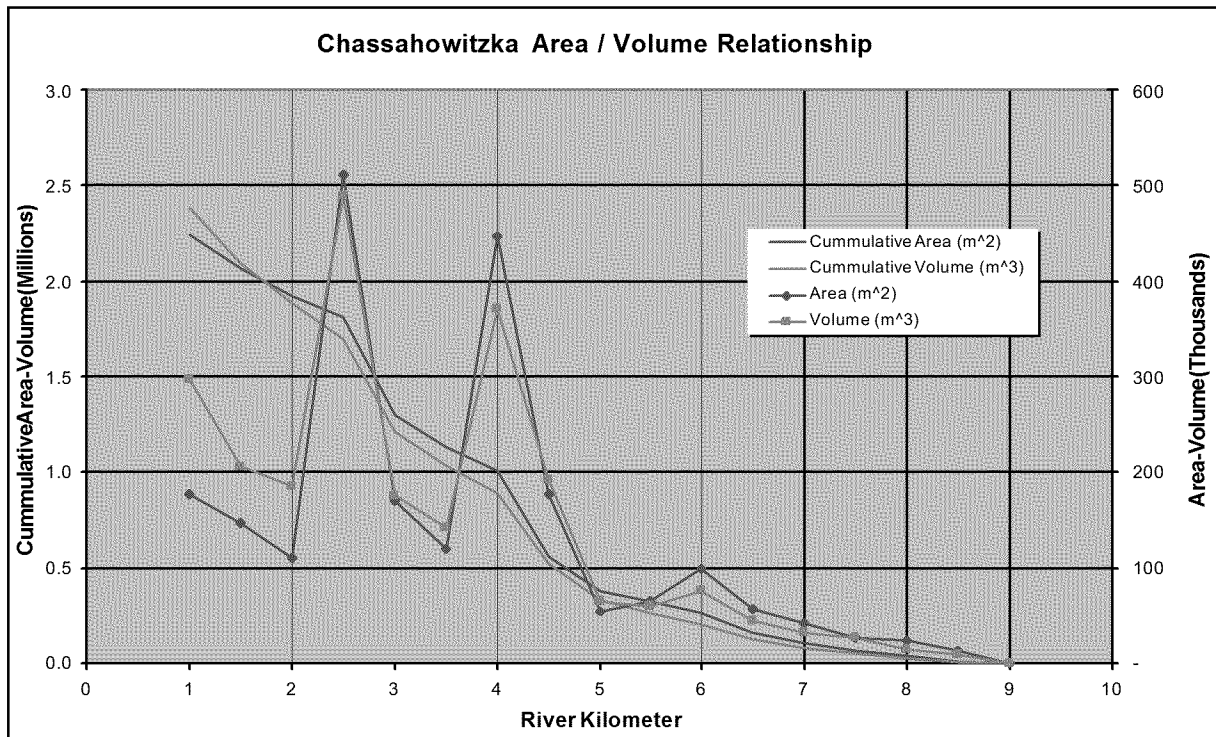


Figure 3-4 Cumulative upstream volume and area vs river kilometer at mean tide level.

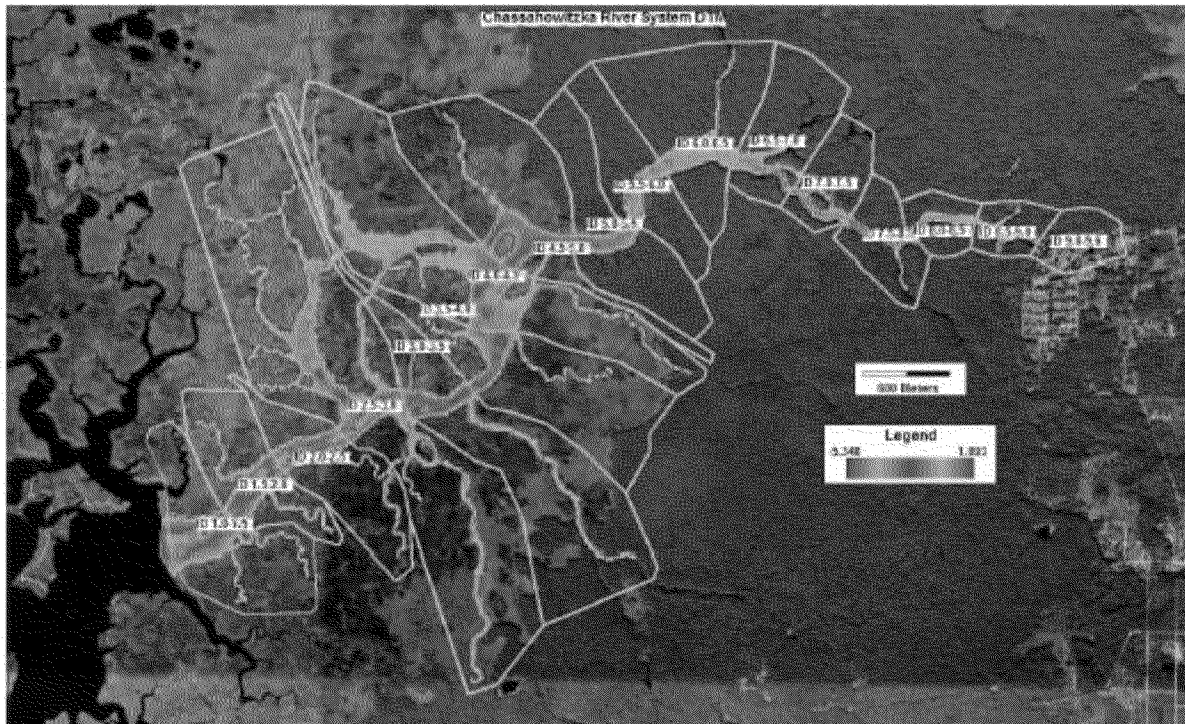


Figure 3-3 Area-volume segmentation polygons for the Chassahowitzka River system

Table 3-1 Volume, area and shoreline length by river kilometer for the Chassahowitzka River system.

Rkm ID	Rkm	Area (m ²)	Storage (m ³)	Length (km)	Average Depth (m)	Cumulative		
						Area (m ²)	Storage (m ³)	Length (km)
1.0-1.5	1	177,300	296,908	2.498	1.67	2,245,800	2,388,000	68.959
1.5-2.0	1.5	147,200	205,239	4.684	1.39	2,068,500	2,091,092	66.461
2.0-2.5	2	110,800	184,959	4.555	1.67	1,921,300	1,885,853	61.777
2.5-3.0	2.5	510,700	489,935	19.449	0.96	1,810,500	1,700,894	57.222
3.0-3.5	3	171,000	175,353	7.183	1.03	1,299,800	1,210,959	37.773
3.5-4.0	3.5	120,600	142,344	4.052	1.18	1,128,800	1,035,606	30.590
4.0-4.5	4	447,600	370,316	10.024	0.83	1,008,200	893,262	26.538
4.5-5.0	4.5	177,300	191,605	4.334	1.08	560,600	522,946	16.514
5.0-5.5	5	54,400	65,838	0.988	1.21	383,300	331,341	12.180
5.5-6.0	5.5	65,300	59,501	1.049	0.91	328,900	265,503	11.192
6.0-6.5	6	98,900	76,005	2.315	0.77	263,600	206,002	10.143
6.5-7.0	6.5	57,000	45,152	1.774	0.79	164,700	129,997	7.828
7.0-7.5	7	42,100	32,563	1.727	0.77	107,700	84,845	6.054
7.5-8.0	7.5	27,500	26,998	1.734	0.98	65,600	52,282	4.327
8.0-8.5	8	24,000	15,619	1.011	0.65	38,100	25,284	2.593
8.5-9.0	8.5	13,800	9,593	1.441	0.70	14,100	9,665	1.582
9.0-9.6	9	300	72	0.141	0.24	300	72	0.141

3.2 Bottom Habitats

SAV occurs throughout most of the river with a gradual decline in density with distance downstream. Common macrophytes include *Vallisneria americana* (American eelgrass), pondweed, *Najas guadalupensis* (southern naiad), Eurasian water milfoil, and *Hydrilla verticillata*. Filamentous macroalgae, including *Lyngbya* sp. and *Chaetomorpha* sp., are also abundant.

An extensive marsh system occurs at the mouth of the river and upper estuary. Seaward of the marsh, the water is generally shallow and interspersed with numerous islands. Some patchy seagrass exists in the estuary seaward of the marsh complex, but macroalgae are more prevalent (Dixon and Estevez 2001). Both attached macroalgae (e.g., *Caulerpa* spp.) and unattached (drift) forms are frequently observed in this estuary.

The physical and chemical characteristics of the Chassahowitzka River are generally favorable for growth of submersed aquatic vegetation (SAV). Mote Marine Lab (MML) conducted seven surveys from 1996 through 2000. (Dixon and Estevez 1997, 1998, 2001. Toutant et al. 2004) from Chassahowitzka Main spring to a radius of stations approximately 9.6 km offshore. EMAP protocols were used to identify 38 polygons, eight of which were within the river proper. Two stations were randomly selected in each of the polygons during each sampling episode resulting in a total of 532 samples for the duration of this study. In addition to the SAV measurements, water quality samples were collected for instrument parameters, color, turbidity, chlorophyll and nutrients at 20 of the

polygons. Seventeen water quality samplings were conducted between May 1996 and May 2000.

In 2005, MML (See Appendix 4 - Leverone 2006) returned to conduct an additional survey at 0.5 km intervals from Rkm 0 to Rkm 9. A transect was established at each of the nineteen intervals and ten quarter-meter square quadrats were analyzed along each transect (n=190).

During an overlapping multi-year (1998-2000) research project conducted by University of Florida (UF) (Frazer et al. 2001), macroalgae, submersed macrophytes, and the periphyton associated with submersed macrophytes were sampled from five stations along each of 20 regularly spaced (approximately 0.25 km) transects (n=100) from the main spring to the marsh complex Figure 3-5 illustrates the location of the MML and UF stations.

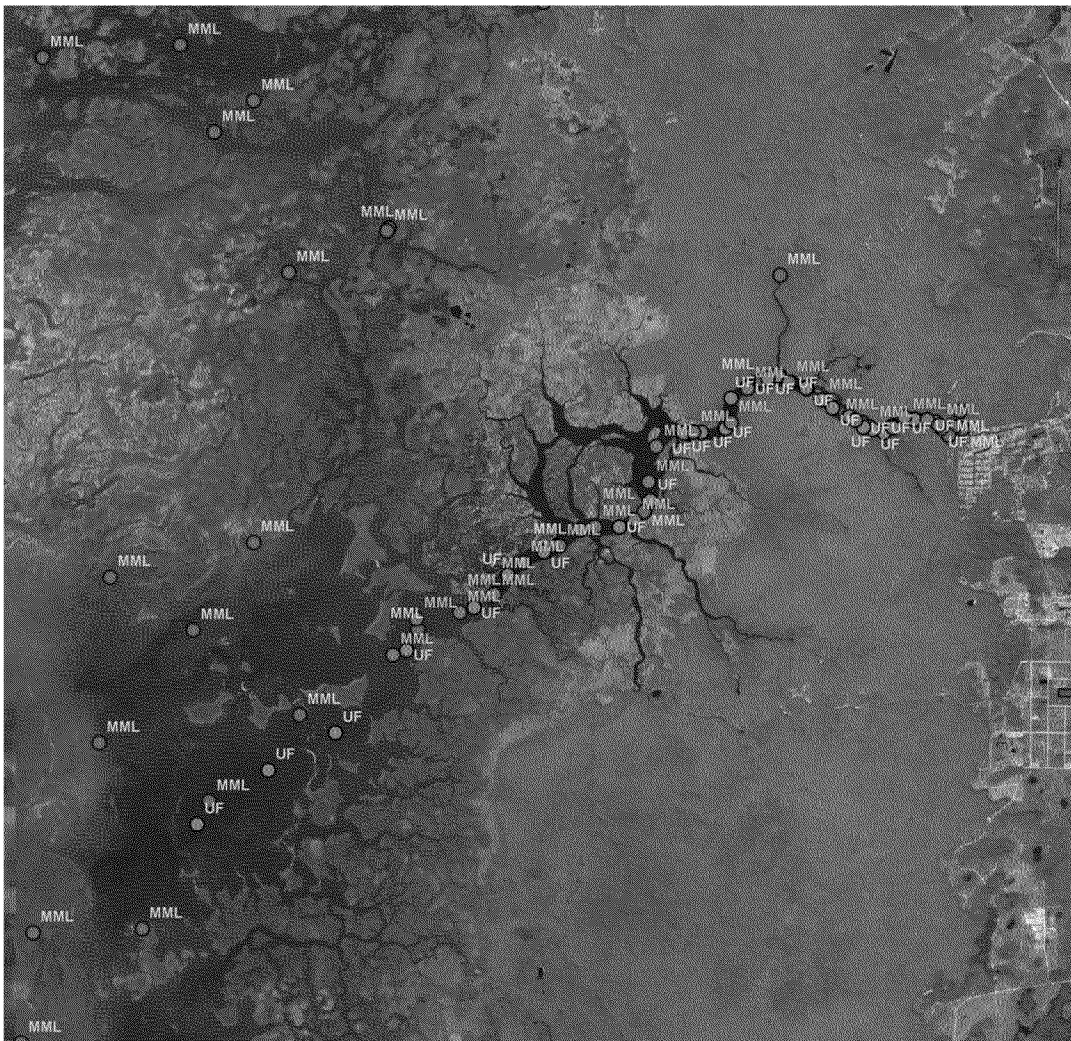


Figure 3-5 SAV sampling locations - MML and UF 1996-2005

A complete listing of the macrophytes and macroalgae observed along with their frequency of occurrence in the Chassahowitzka River during the three sampling events

conducted in 1998-2000 by UF (Frazer 2001) and the eight sampling events conducted by MML (Dixon and Estevez 2001, Leverone 2006) is provided in Table 3-2. The four highest frequencies are highlighted. Macroalgae was described by MML only as “drift” or “bare” species and is therefore not included in table.

Table 3-2 Frequency of occurrence (% of stations sampled) of macrophyte and macroalgal species for the Chassahowitzka River by year for 1997-2006.

Year (source)	1997 (1)	1998 (1)	1998 (2)	1999 (1)	1999 (2)	2000 (1)	2000 (2)	2006 (3)	Average 1997 - 2006
Taxon									
<i>Acetabularia crenulata</i>	0	0	0	3	0	2	0		1
<i>Ceratophyllum demersum</i>	0	0	3	0	3	0	6	0	2
<i>Chaetomorpha</i> sp.	0	0	27	0	21	0	61	0	14
<i>Chara</i> spp.	0	2	0	0	0	0	0	0	0
<i>Fontinalis</i> sp.	0	0	0	0	0	0	1	0	0
<i>Gracilaria</i> sp.	0	0	1	0	4	0	22	0	3
<i>Halodule wrightii</i>	0	0	0	3	0	0	0	0	0
<i>Hydrilla verticillata</i>	13	11	48	9	18	3	13	10	16
<i>Lyngbya</i> sp.	0	0	29	0	35	0	26	0	11
<i>Myriophyllum spicatum</i>	22	27	17	34	12	4	11	35	20
<i>Najas guadalupensis</i>	22	6		9	49	2	26	12	18
<i>Potamogeton pectinatus</i>	22	17	33	25	25	2	21	18	20
<i>Ruppia maritima</i>	0	13	1	0	1	4	15	13	6
<i>Sagittaria kurziana</i>	0	0	2	0	3	0	0	0	1
<i>Thalassia testudinum</i>	0	2	0	0	0	0	0	0	0
Unvegetated	25	20	0	0	0	5	0	0	6
<i>Vallisneria americana</i>	22	14	38	16	34	2	23	19	21
<i>Zanichellia palustris</i>	0	0	0	0	0	0	0	5	1
Misc. Algae (Drift/Filamentous) (includes <i>Lyngbya</i> sp.)	63	59	0	84	0	15	0	0	28

Sources: 1) Dixon and Estevez, 2001 2) Frazer et al. 2001 3) Leverone 2006

frequency.xls

The most frequently encountered macrophytes were *Vallisneria americana*, *Myriophyllum spicatum*, *Potamogeton pectinatus* and *Najas guadalupensis*. Of these, all exhibited temporal and spatial variability in their patterns of distribution. Time series of frequency as a function of river kilometer is depicted in Figure 3-6 for *Vallisneria americana*, *Myriophyllum spicatum* and *Potamogeton pectinatus*. No pattern could be discerned. Mote Marine Laboratory (Toutant et al. 2004) completed a detailed change analysis of their data and cite a number of factors which are suspected of contributing the variability. An intense progression of algal blooms (initially a blue green, followed by diatoms) persisted in the near coastal waters from Weeki Wachee to Crystal River from March until September 1998. Rainfall during late 1997 and early 1998 produced cumulative values well in excess of historical means which influenced both surface and groundwater flows. Mean monthly flows in the adjacent Withlacoochee River were approximately four times historical averages. The effect of reduced salinity and transparency resulted in a measurable loss of some species of SAV and an increase in unvegetated bottom areas in coastal areas of the Refuge.

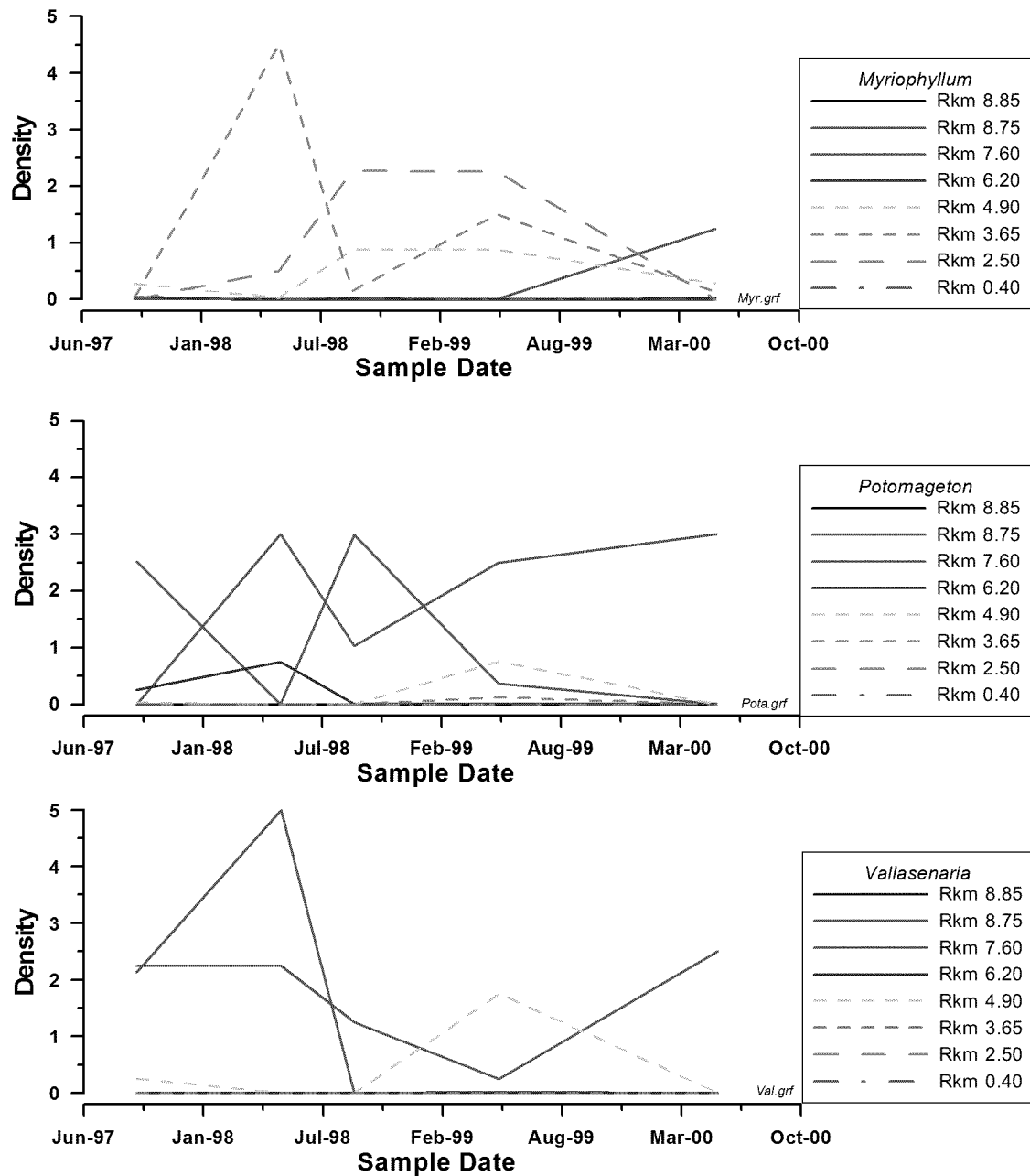


Figure 3-6 Spatial and temporal variation of density (# / m2) of three common species of SAV in the Chassahowitzka River. (Data from Dixon and Estevez 2001)

3.3 Sediments

In general, the bottom sediments in the Chassahowitzka River are dominated by sand and mud or a combination of the two substrate types (Frazer et al. 2001). The nature of the bottom substrate is generally determined by stream velocity. Sand, silt and mud are typical of streams with low to moderate flows, like the Chassahowitzka River (Clewett et al. 2002). Characterization of sediments in the river appears to be limited to those samples collected in 1996 by Mote Marine Laboratory (Dixon and Estevez 1998) and again in 2005 in association with benthic community analysis reported by Janicki Environmental Inc. (2006). (See Appendix 5) Based on analysis of core samples sieved through a 2-mm mesh (see Leverone 2006 for methods used), Janicki Environmental, Inc. (2006) note that sediments downstream from Rkm 5 in 2005 were primarily fine and very fine sands with a mean grain size between 62.5 and 250 μm (mean Krumbein phi (ϕ) scale values between 2 and 4) (Figure 3-7). Medium and coarse sand-sized particles ranging in size from 0.25 to 1 mm (ϕ between 0 and 2) dominated the upstream sediments. Fine-grained sediments (silts and clays) accounted for ~30 percent of the sediment volume near the mouth of the river, more than 50% of the volume at Rkm 4.5, and ~15% of the sediment volume at Rkm 8 (Janicki Environmental, Inc. 2006) The peak in silt and clay distribution at Rkm 4.5 roughly corresponds to the transition zone between deciduous forest and marsh. Similar patterns in the distribution of fine and coarser-grained sediments and silt+clay were observed by Dixon and Estevez (1998) based on analysis of un-sieved core samples collected in 1997.

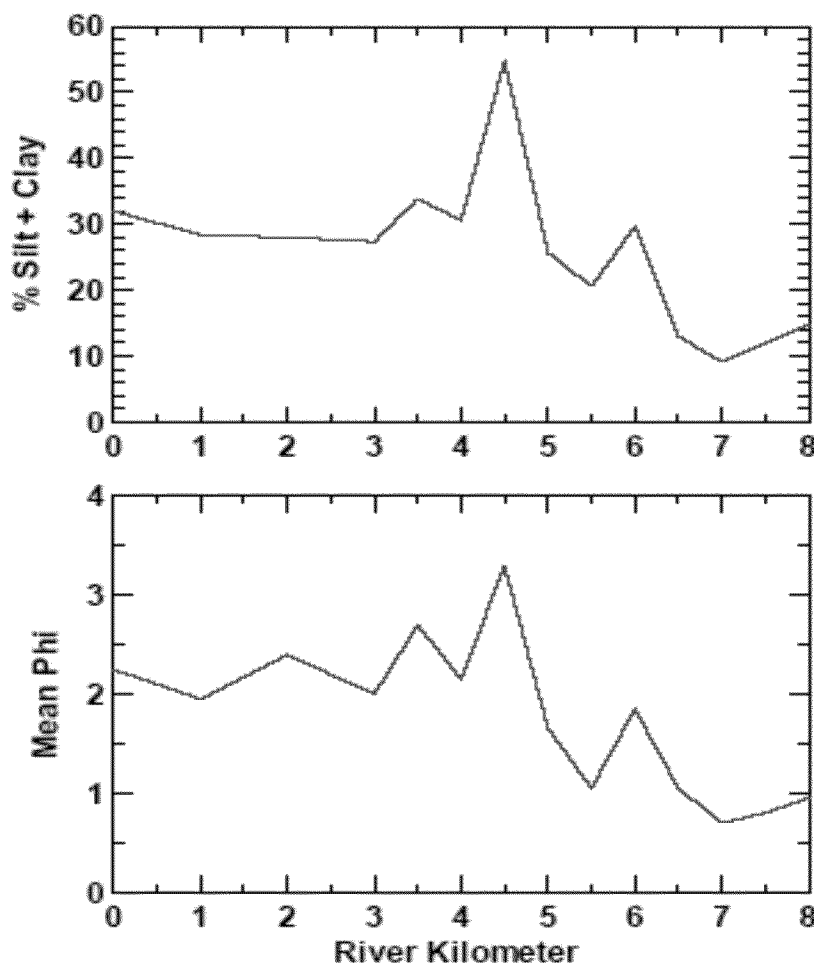


Figure 3-7 Mean percentage silt plus clay by volume (upper panel) and grain size (Krumbein phi value, lower panel) by river kilometer in 2-mm sieved sediment core samples collected from the Chassahowitzka River in May and September 2005 (reproduced from Janicki Environmental, Inc. 2006).

3.4 Tidal Wetlands and Riparian Habitats

The Chassahowitzka River is imbedded within an extensive tidal forested wetland system that transitions to saltwater marsh approximately 4 km downstream from the river headwaters. This transition and the extent of wetlands surrounding the river channel are clearly evident in aerial photography of the region (Figure 3-8). Characterization of these coastal wetlands has been the focus of numerous reports completed during the past two decades. For example, Simons (1990) and Wolfe et al. (1990) provide a general overview of wetland and upland vegetation for the area known as the Springs Coast, an extensive portion of the west coast of Florida ranging from the Pithlachascotee River basin northward to the Waccasassa River basin. Other studies, including those completed by the Southwest Florida Water Management District (1989), Kelly (1994), Florida Marine Research Institute (1997), Dixon and Estevez (1998), Frazer et al. (2001a, b), Clewell et al. (2002), Hoyer et al. (2004), Toutant et al. (2004) and Frazer et

al. (2006) provide specific information on the vegetative communities associated with the Chassahowitzka River.

Common tree species in the forested wetland systems surrounding the river include red maple (*Acer rubrum*), cabbage palm (*Sabal palmetto*), southern red cedar (*Juniperus virginiana* var. *silicicola*), sweetbay (*Magnolia virginiana*), laurel oak (*Quercus laurifolia*), water oak (*Quercus nigra*), sweetgum (*Liquidambar styraciflua*), pignut hickory (*Carya glabra*), basswood (*Tilia caroliniana*) and bald cypress (*Taxodium distichum*). Emergent and submersed aquatic vegetation in the upper river include tape grass (*Vallisneria spiralis*), sago pondweed (*Potamogeton pectinatus*), Illinois pondweed (*Potamogeton illinoensis*) water milfoil (*Myriophyllum spicatum*), hydrilla (*Hydrilla verticillata*), southern naiad (*Najas guadalupensis*), cattail (*Typha* spp.) and reeds (*Phragmites* sp.). Marine and freshwater algae, including *Chaetomorpha*, *Cladophora*, *Enteromorpha*, *Gracilaria*, *Lyngbya* and *Schizothrix* are commonly found in the upper and lower portions of the river. Sawgrass (*Caldium jamaicense*), cattail, widgeon grass (*Ruppia maritima*), cabbage palm and black needlerush (*Juncus roemerianus*) are common at the interface or transition zone between the forested wetland and salt marsh systems. Black needlerush is the dominant salt marsh plant in the Chassahowitzka area.

The shoreline of the Chassahowitzka River was characterized along with six other rivers on the west coast of Florida by Clewell et al. (2002) (See Appendix 6) in a study designed to compare vegetation distribution and salinity across multiple systems. Field studies were conducted in 1989 and 1990 and compared to long-term salinity records. The focus of the field collection was to describe the distribution of herbaceous plants (including dominant marsh species) along the riverbank. Presence / absence was recorded for each plant species. A total 84 sites were investigated along the Chassahowitzka River, and 42 species were identified as depicted in Table 3-3.

Using data from all seven rivers, Clewell et al. (2002) noted several potential vegetation breaks and postulated the question "Do these break points correlate with sufficient precision across rivers with regard to salinity to make them useful as ecological indicators of the salinity regime?" After analysis, the authors concluded "For these reasons, breaks in vegetation that seem apparent as one travels by boat may be indicative of general salinity conditions but are not reliable as predictors of specific salinity regimes." Factors cited as contributing to a lack of good correlation between plant occurrences and salinity included the narrow nature and relatively high frequency of disturbance of riverbank habitat with respect to adjacent marsh or forested habitats. On a relatively coarse scale, land-use/cover information available from the Southwest Florida Water Management District Mapping and GIS Section provided a means for evaluating tidal wetland and riparian habitats associated with the Chassahowitzka River. For this purpose, land use/cover in a 1,640 foot buffer area surrounding a polygon approximating the location of the main stem of the river (Figure 3-8) was used to clip geospatial polygons assigned classifications based on the Florida Land Use, Cover and Forms Classification System (Florida Department of Transportation 1999). Geospatial data processing was conducted using ESRI ArcMap and Geographic Information System layers representing land use/cover classifications for the area in 1990, 1995, 1999 and 2004 through 2007 (Southwest Florida Water Management District 2003a,b, 2004a, 2007a,b,c, 2008).

Table 3-3 Percentage of Chassahowitzka sites where species occurred (Clewett et al. 2002)

Species	Percent of Occurrence
<i>Cladium jamaicense</i>	74
<i>Juncus roemerianus</i>	48
<i>Typha domingensis</i>	36
<i>Crinum americanum</i>	15
<i>Sagittaria lancifolia</i>	14
<i>Acrostichum danaeifolium</i>	13
<i>Baccharis halimifolia</i>	11
<i>Myrica cerifera</i>	11
<i>Sagittaria subulata</i>	11
<i>Aster carolinianus</i>	9
<i>Senecio glabellus</i>	9
<i>Persea palustris</i>	8
<i>Rumex verticillatus</i>	8
<i>Distichlis spicata</i>	6
<i>Magnolia virginiana</i>	6
<i>Samolus valerandi</i>	6
<i>Solidago stricta</i>	6
<i>Alternanthera philoxeroides</i>	5
<i>Lythrum alatum</i>	5
<i>Scirpus americanus</i>	5
<i>Spartina alterniflora</i>	5
<i>Cicuta maculata</i>	4
<i>Lycium carolinianum</i>	4
<i>Sabal palmetto</i>	4
<i>Saururus cernuus</i>	4
<i>Acer rubrum</i>	3
<i>Cornus foemina</i>	3
<i>Iris hexagona</i>	3
<i>Itea virginica</i>	3
<i>Paspalidium geminatum</i>	3
<i>Scirpus robusta</i>	3
<i>Ampelopsis arborea</i>	1
<i>Aster tenuifolius</i>	1
<i>Boehmeria cylindrical</i>	1
<i>Carya aquatica</i>	1
<i>Ilex cassine</i>	1
<i>Phragmites australis</i>	1
<i>Pluchea odorata</i>	1
<i>Pontederia cordata</i>	1
<i>Quercus geminata</i>	1
<i>Tilia caroliniana</i>	1
<i>Ulmus americanus</i>	1

The Chassahowitzka River transitions from freshwater forest to saltwater marsh at approximately Rkm 5. There is a notable vegetation demarcation visible in the aerial photograph (Figure 3-8), which identifies the location of the extensive saltwater marsh system. With the exception of the Bays and Estuaries and Gulf of Mexico land use/cover classes, land use/cover in the river buffer area exhibited little change in the years examined between 1990 and 2007 (Table 3-5). Land classified as Bays and Estuaries declined from 1,198 to 1,200 acres in the earlier years examined to approximately 870 acres in the most recent years. In contrast lands classified as Gulf of Mexico increase from 0 acres in the 1990s to approximately 300 acres in the 2000s. Lands classified as Salt Marsh covered approximately 1,400 acres in 1990 and approximately 1,420 acres in all subsequent years examined. Inter-annual differences in other land use/cover classifications were generally on the order of only a few acres.

Table 3-5 Land-use by acre for a 1640 foot buffer area around and including the main stem of the Chassahowitzka River as shown in Figure 3-8. Land use/cover classes based on the Florida Land Use, Cover and Classification System (Florida Department of Transportation 1999).

Class	Description	LU1990 Acres	LU1995 Acres	LU1999 Acres	LU2004 Acres	LU2005 Acres	LU2006 Acres	LU2007 Acres
1100, 1200, 1300	Urban	79.3	79.5	82.8	86.0	86.0	86.0	86.0
1800	Recreational	0.0	2.2	2.2	2.2	2.2	2.2	2.2
3100	Herbaceous (Dry Prairie)	0.4	0.0	0.0	0.0	0.0	0.0	0.0
4340	Hardwood – Confer Mixed	5.3	5.7	5.7	5.7	5.7	5.7	5.7
5400	Bays and Estuaries	1200.0	1177.6	1177.6	873.5	873.5	872.9	872.9
5720	Gulf of Mexico	0.0	0.0	0.0	304.1	304.1	304.7	304.7
6110	Bay Swamps	4.6	4.1	4.1	4.1	4.1	4.1	4.1
6150	Stream and Lake Swamps (Bottomland)	980.6	982.7	981.4	978.2	978.2	978.2	978.2
6300	Wetland Forested Mixed	44.7	45.7	45.7	45.7	45.7	45.7	45.7
6420	Saltwater Marshes	1404.7	1423.9	1421.8	1421.8	1421.8	1421.8	1421.8
7400	Disturbed Lands	1.7	0.0	0.0	0.0	0.0	0.0	0.0
	Total	3721.3	3721.3	3721.3	3721.3	3721.3	3721.3	3721.3



Figure 3-8 Aerial photograph illustrating the 1,640 foot (500 m) buffer and marsh edge.

Tidal wetlands associated with coastal rivers of the southeastern United States and elsewhere are susceptible to degradation associated with droughts, anthropogenic alteration of natural freshwater inflows or groundwater discharge, land-use changes, hurricanes and other storms, climate change, sea-level trends and sediment or substrate subsidence (e.g., see Boesch et al. 1994, Brinson and Malvarez 2002, Kennish 2004, Doyle et al. 2007, Stedman and Dahl 2008). Studies addressing effects of salinity increases associated with these factors are particularly relevant to the development of minimum flow requirements for the Chassahowitzka River system and other coastal rivers in the Southwest Florida Water Management District, where flow reductions may alter longitudinal salinity patterns within river channels and associated wetlands. Effects of salinity on changes in cypress-dominated and mixed bottomland swamps in tidal segments of southeastern coastal rivers have been considered by numerous investigators. In a review of sea-level rise and coastal forests of the Gulf of Mexico, Williams et al. (1999) describe changes associated with sea level variation during the Holocene and summarize recent changes have been attributed to increased salinity in the Mississippi River delta and south Florida. More recent summaries of saltwater induced changes in southeastern tidal swamps are provided by Conner et al. (2007) and Krauss et al. (2007). As part of a comprehensive review of tidal floodplain forests of the Suwannee River, Light et al. (2002) discuss potential increases in the abundance of salt-tolerant species under various flow-reduction scenarios. In the Northwest Fork of the Loxahatchee River in southeast Florida, recent decline of floodplain swamp vegetation,

including bald cypress, has been associated with increased salinity (South Florida Water Management District 2002). In response to this environmental degradation and to preserve existing and stressed floodplain swamp communities, a minimum flow for the Loxahatchee River was established to maintain salinities less than 2 ppt at selected sites along the river corridor. Based on review of published salinity tolerance information for common tree species within tidal forested wetlands, including bald cypress and various hardwood species, the Suwannee River Water Management District (2005) also identified a 2 ppt salinity criterion for consideration in their development of minimum flows for the lower segment of the Suwannee River.

The effects of sea-level rise and increasing salinity have also been evaluated for hydric hammocks, a common forested wetland type extending along the west coast of Florida from the southern Hernando County line north to the vicinity of the St. Marks River. Reduction in the aerial coverage of hydric hammocks, which are typically dominated by cabbage palm, southern red cedar, a mixture of hardwood trees and loblolly pine (*Pinus taeda*), has been extensive during the past century (see review by Williams et al. 2007).

DeSantis et al. (2007) attributed recent declines in populations of cabbage palm and southern red cedar at Waccasassa Bay State Preserve to sea-level increase and drought, noting that recent rates of decline have exceeded predictions derived from previous studies of the area. Castaneda and Putz (2007) documented more than a 17 percent decline in coastal forest in the Waccasassa Bay State Preserve between 1973 and 2003 as a result of forest replacement with salt marsh species. Modeled wetland changes associated with various sea level increase scenarios for the St. Marks National Wildlife Refuge area also demonstrate potential increases in salt marsh habitat and losses in forested habitat with increased sea levels (Doyle et al. 2003). According to analyses conducted by Raabe et al. (2004), as cited by Williams et al. (2007), decline of hydric hammock vegetation along the Big Bend coastline of Florida since the mid-1800s has been less pronounced in areas with high freshwater discharge, e.g., near the Suwannee and Weeki Wachee Rivers. Field investigations of the survival of transplanted cabbage palm seedlings at Waccasassa Bay and at the Chassahowitzka National Wildlife Refuge (an area of relatively low salinity), provide some support for the mitigation of adverse salinity-effects in areas of higher freshwater discharge (Perry and Williams 1996). However, Williams et al. (2007) caution that “[g]ood quantification of the effect of freshwater discharge on the rates of forest canopy loss and coastal forest retreat requires further study”.

CHAPTER 4 - TIDE, SALINITY & WATER QUALITY

4.1 Tide

The tides along the Springs Coast are mixed semidiurnal; a higher high and lower high tide, as well as a higher low and lower low tide, each day is possible. The Chassahowitzka River is tidally affected along its entire length and water levels normally fluctuate 0.5 to 1.0 foot near its headwaters. Salinity and flow relationships in the Chassahowitzka River were studied by Yobbi and Knochenmus (1989) using data on high tides, salinity and flow. Tide-stage measurements were continuously collected at stations located 5.14 and 8.60 km (corresponding to Yobbi and Knochenmus's 2.70 and 4.85 river miles) upstream of the mouth of the Chassahowitzka River.

Table 4-1 provides a summary of tide-stage data for the Chassahowitzka River during 1984-1985. The average diurnal tidal ranges are approximately 2.1 feet near the mouth of the river. Seasonal variation exists, with tides being higher on the average in summer and fall than in winter and spring.

Table 4-1 Summary of monthly average tide-stage data for the Chassahowitzka River (Yobbi and Knochenmus 1989)

Tide	Period of Record	Month											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Chassahowitzka River, Rkm 5.14													
Higher high	1984-1985	---	1.66	1.87	1.86	1.68	1.67	1.64	1.97	---	2.14	2.39	---
Lower low	1984-1985	---	-.31	-.39	-.44	-.55	-.56	.45	-.12	---	-.03	.19	---
Chassahowitzka River, Rkm 8.60													
Higher high	1966-1978	1.91	1.88	1.84	1.76	1.81	1.92	1.99	2.05	2.06	1.99	1.99	2.05
Lower low	1966-1978	1.29	1.26	1.21	1.20	1.29	1.41	1.49	1.52	1.54	1.41	1.37	1.39
Stage data are in feet above or below sea level. “---” signifies no data.													

Yobbi and Knochenmus conducted multiple linear-regression analysis to relate the maximum upstream extent of 5- and 3-ppt salinities to daily mean discharge and recorded high-tide stage at Rkm 5.14. The results of their regression analysis indicated that discharge is the only independent variable that significantly affects the maximum upstream extent of the 5- and 3-ppt salinities. In 1988, Yobbi and Knochenmus wrote:

High tides between 1.50 and 2.55 feet appear to be of minor importance in substantially influencing the maximum extent of salinity intrusion, or else tide stage was confounded with discharge, and discharge alone is sufficient to describe location of the salinities.

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4.2 Salinity – Longitudinal

Salinity in the Chassahowitzka River systems may vary from fresh to brackish at the headwater and increases sharply as water moves through the marsh and into the estuary, mixing with more saline Gulf of Mexico water. Frazer et al. (2001) conducted sampling of the Chassahowitzka River during ten quarterly events between the summer of 1998 and the winter of 2000-2001. Mote Marine Laboratory (Dixon and Estevez 2001) sampled in May and September from 1996 – 2004 and the District (unpublished data) sampled every other week from September 2007 through August 2008. A summary of the values is provided in Table 4-2 and is graphically depicted in Figure 4-1.

Table 4-2 Salinity by river kilometer, 1996-2008

Km Range	n=	Min	25th Pct	Mean	Median	75th Pct	Max
0.0-1.0	87.0	2.8	8.8	12.9	12.9	16.8	25.1
1.1-2.0	160.0	2.4	6.6	11.2	11.0	14.6	22.2
2.1-3.0	225.0	2.0	4.4	9.0	8.5	12.3	24.3
3.1-4.0	161.0	1.9	3.1	6.2	4.5	7.7	22.3
4.1-5.0	150.0	1.5	2.3	5.1	3.5	7.0	14.1
5.1-6.0	132.0	1.4	1.9	2.8	2.3	2.9	12.3
6.1-7.0	223.0	1.3	2.0	2.9	2.6	3.3	10.3
7.1-8.0	192.0	0.9	1.6	2.1	2.0	2.7	5.0
8.1-9.0	395.0	0.1	1.1	1.7	1.6	2.2	4.1

Chass_Sal_Bins.xls

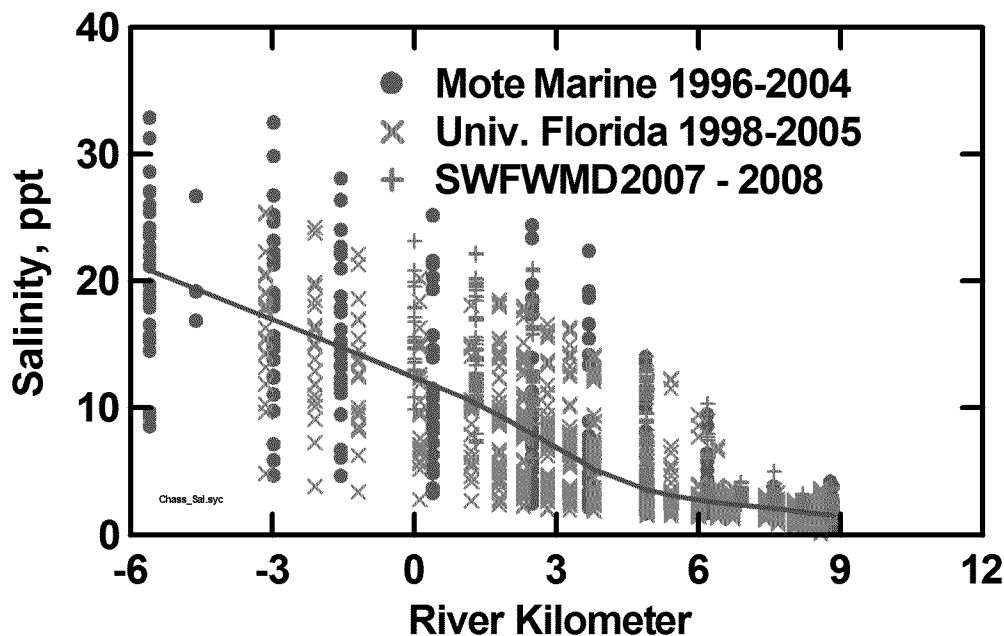


Figure 4-1 Longitudinal salinity 1996-2008

Salinity is a critical parameter for setting an estuarine MFL. Consequently, considerable effort was expended in an attempt to relate salinity to both the resources of concern as well as flow, which is the sole management option. Of necessity, numerous approaches were tested to determine the best technique for relating flow and salinity. This section and subordinate sub-sections include a description of observed salinity conditions and predicted salinity by river location.

Frazer et al. (2001) recorded mean salinities in the Chassahowitzka River between 1.3 and 2.6 ppt at river kilometer 8.6. Within specific sampling periods, mean salinities were fairly uniform along the river above the marsh complex and were generally less than 5 ppt. Downstream of the marsh transition zone, mean salinity increased rapidly with distance into the estuary and significant variation in values among sampling periods was observed. The variation in mean values is a result of both the tidal stage at time of sampling and the discharge characteristics of the river. The highest recorded salinities were during periods when river flow was correspondingly low (Frazer et al. 2001).

The combined mean salinities recorded by Mote Marine Laboratory, University of Florida and the District in the Chassahowitzka River were between 0.1 and 4.1 ppt near the Main Spring (Rkm 8-9). At river kilometer zero, where the river loses confinement, the mean and median salinity is 12.9 ppt and additional mixing with Gulf water occurs beyond Rkm 0. Mean salinities above the marsh complex were generally less than 5 ppt. Downstream of the marsh transition zone, mean salinity increased with distance into the estuary. Significant variation in values among sampling periods was observed in this segment of the Chassahowitzka River, which is similar to the 2001 results recorded by Frazer et al. (2001)

Additionally, Yobbi and Knochenmus (1989) made the following observation:

The locations of low-concentration salinities appear to be less sensitive to changes in flow and tides and migrate over a smaller distance than high-concentration salinities. The 25-ppt salinity had a range in movement that was more than three times as great as the range in movement of the 3-ppt salinity.
[page 16]

Regressions predicting the salinity at locations along the Chassahowitzka River were developed. River kilometer, flow, and tide/stage were evaluated as candidate independent variables. This section describes the results.

A regression of the form below was evaluated to estimate salinity at any location along the Chassahowitzka River. The initial river domain was from -3 to +9 km. Several flow terms were investigated, including Flow, $\ln(\text{Flow})$, and Flow^{-1} . The results were generally similar and the final form chosen used Flow, resulting in the following equation:

$$\text{Salinity} = \beta_0 + \beta_1 * \text{Flow} + \beta_2 * \text{Rkm}$$

Where: Salinity in ppt,
Flow is spring flow (cfs), and
Rkm is river kilometer as previously defined.

The Chassahowitzka River estuary is reasonably well mixed vertically, and waters along most of the estuary are essentially uniform from top to bottom. Therefore, surface and

bottom salinities are not distinguished in the regression analysis, which was based on the salinity data collected by MML during 1996 through 2004 (Dixon and Estevez 2001 supplemented with unpublished data from Dixon and Estevez), and by the District during 2007 through 2008 (unpublished). In addition, the flow used in the regression refers to the discharge at Chassahowitzka Spring (Heyl 2010).

The investigation using data from both studies reached a strong correlation coefficient: $\text{Adj-}r^2=0.74$ ($n=493$). Because combining the data from the two studies increases the time span, the results from the combined data were adopted for the regression analysis, and the corresponding coefficients are presented below. The salinity regression is graphically depicted in Figure 4-2. Several outlier points (extreme-value salinities away from data cluster at certain river kilometers) were removed from the original data, and this treatment contributed to the improvement in correlation coefficient.

$$\text{Salinity} = 29.3749 - 0.2838 * \text{Flow} - 1.3678 * \text{Rkm}$$

This form has the advantage that one equation can be used to solve for position, flow, or salinity, once the other two terms are known or specified. This equation (herein termed *longitudinal salinity model*, LSM) was used extensively in evaluating the biological MFLs. In addition, the variant forms of the regression equation can be obtained through the following algebraic re-arrangement:

$$\text{Flow} = (\text{Salinity} - \beta_0 - \beta_2 * \text{Rkm}) * (\beta_1)^{-1}$$

and

$$\text{Rkm} = (\text{Salinity} - \beta_0 - \beta_1 * \text{Flow}) * (\beta_2)^{-1}$$

The longitudinal salinity profile under median flow conditions (63 cfs) is given in Figure 4-2. Data includes observations during 1996-2004 (MML) and 2007-2008 (District).

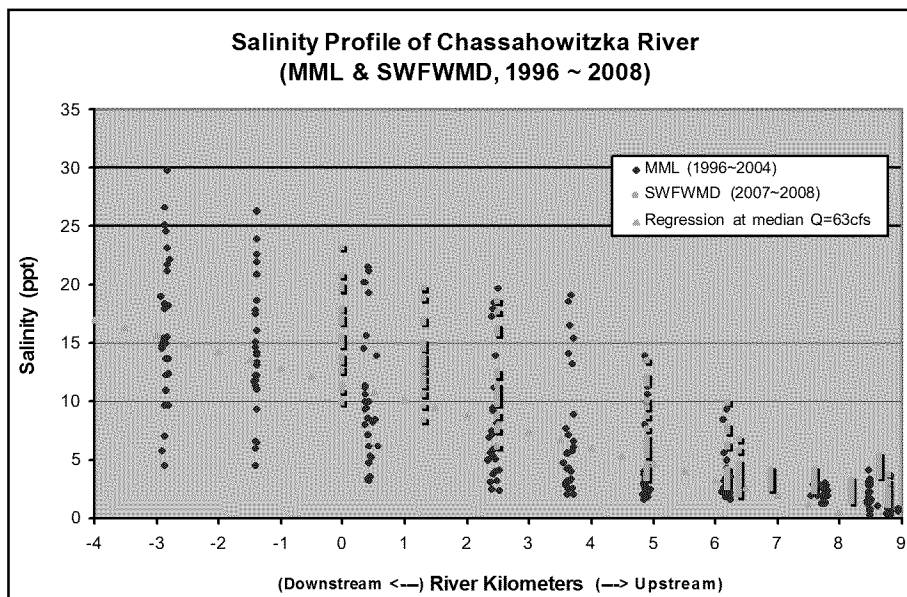


Figure 4-2 Salinity by river kilometer (SWFWMD and Mote Marine Laboratory)

4.2.1 Vertical Salinity Variability

The vertical salinity gradient varies with tides and streamflow. Salinity profiles in the Chassahowitzka River were produced by Yobbi and Knochenmus⁵ (1989) for various streamflow and high-tide conditions. These salinity profiles, provided as Figure 4-3, indicate that the river is reasonably well mixed vertically, for the sampled high tidal and streamflow conditions. Along most of the Chassahowitzka River, water salinity is uniform from top-to-bottom. The ratio of top-to-bottom salinity is generally greater than 85 percent in most portions of the river (Yobbi and Knochenmus 1989).

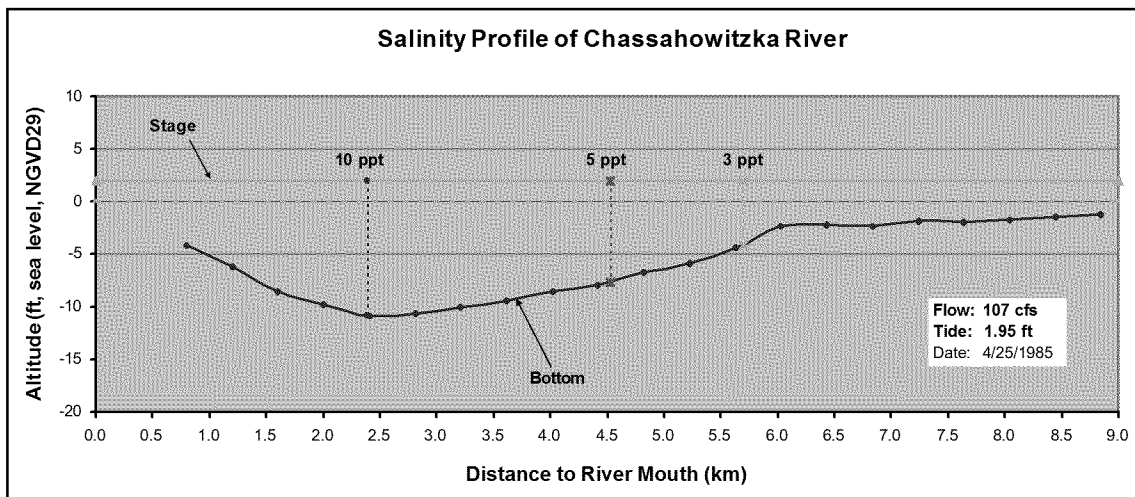
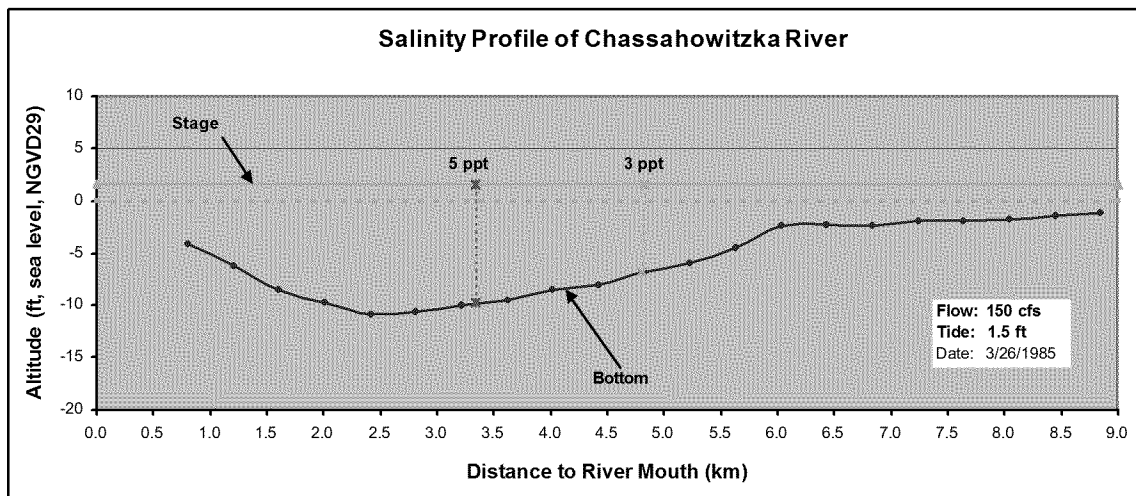


Figure 4-3 Salinity Profiles under various flow conditions (Yobbi and Knochenmus 1989)

⁵ Discharge reported by Yobbi and Knochenmus for this study include discharge from Crab Creek.

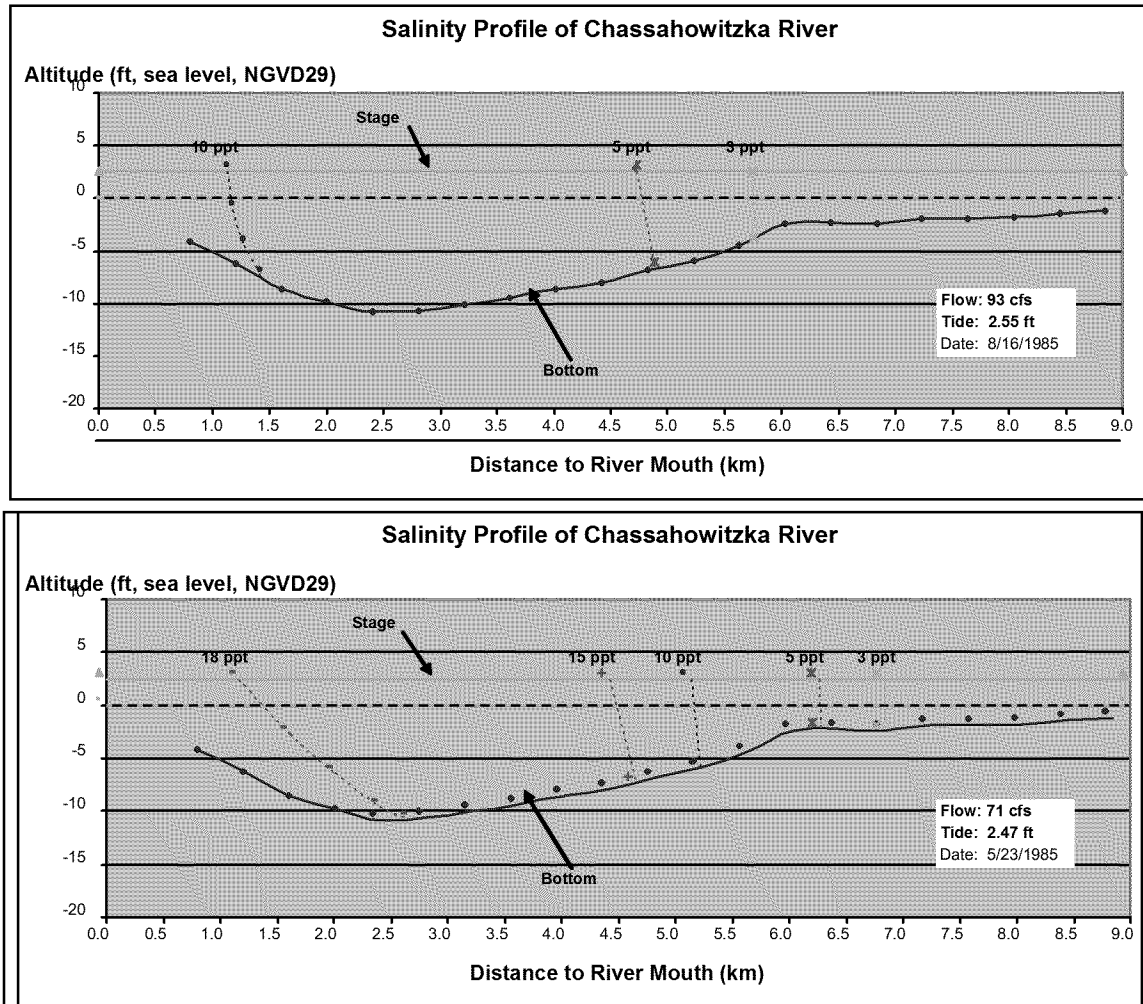


Figure 4-3 (Continued) Salinity Profiles under various flow conditions (Yobbi and Knockenmus 1989)

4.3 Water Quality

Groundwater discharging from the Chassahowitzka Springs may be either fresh or brackish, depending on the tides and water levels in the Floridan aquifer. At low tide, water quality varies among springs in the river system, with concentrations of total dissolved solids increasing from less than 500 mg/l to greater than 5,000 mg/l in springs nearest the Gulf of Mexico. Chloride concentrations may range from less than 150 mg/l to greater than 3,000 mg/l, indicating the water quality is strongly influenced by the coastal transition zone even at low tide (Jones et al. 1997).

A major anthropogenic factor affecting the Chassahowitzka River and many of the Spring Coast vents is the increase in nitrite+nitrate ($\text{NO}_{2+3}\text{-N}$), which is most likely derived from an inorganic source such as inorganic fertilizers applied to residential and golf course turf grasses along the recharge areas (Jones et al. 1997). Using isotopic

signatures and other water quality characteristics, Jones reports that the average nitrate concentrations for the Chassahowitzka Springs range from 0.21 mg/l (Baird Spring) to 0.47 mg/l (Chassahowitzka #1). The mean of the nitrate concentrations for the Chassahowitzka Springs is 0.36 mg/l.

Sampling of the Chassahowitzka River, conducted by Frazer et al. (2001) and Mote Marine Laboratory included a investigations of nitrite+nitrate ($\text{NO}_{2+3}\text{-N}$) concentrations. The Mote Marine Laboratory results are graphically depicted in Figure 4-4.

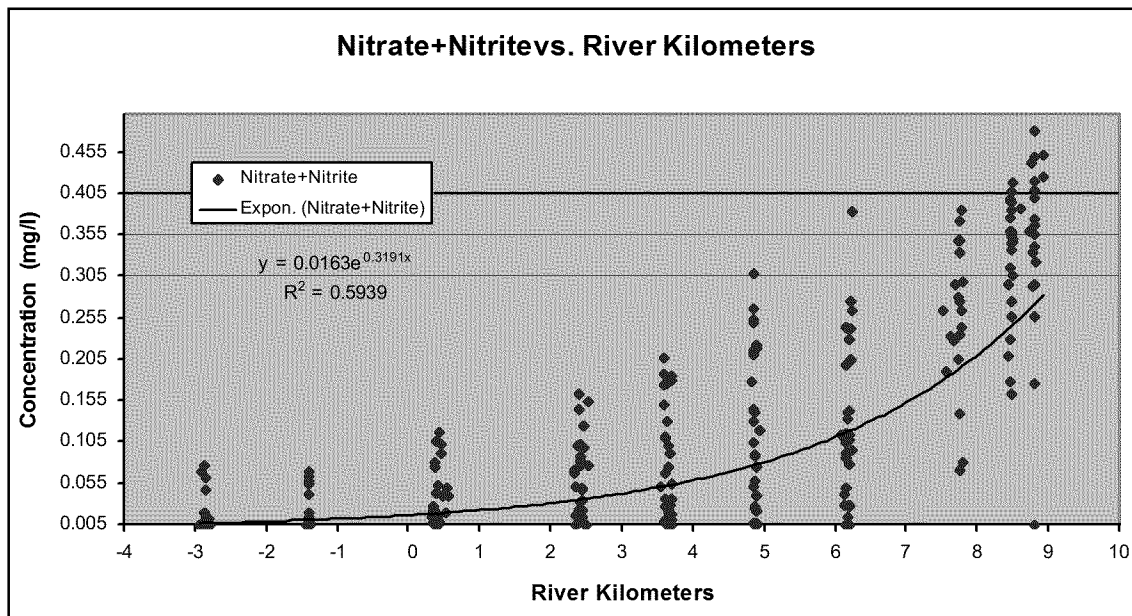


Figure 4-4 Nitrate+nitrite concentrations from the headwaters to the Gulf of Mexico (Mote Marine Laboratory data)

Surface water nitrate concentrations decline with distance from the headwaters. The most abrupt decline in nitrate concentrations were generally observed to occur in the heavily vegetated portion of the river, upstream of the marsh transition zone. Dixon and Estevez (2001) evaluated the loss as a function of simple dilution with Gulf water and concluded that the abrupt loss was the result of assimilation by macro- and Micro-algal species. The relationship between salinity and nitrite+nitrate is provided in Figure 4-5. Simple mixing processes alone would result in a linear relationship between salinity and nitrite-nitrate.

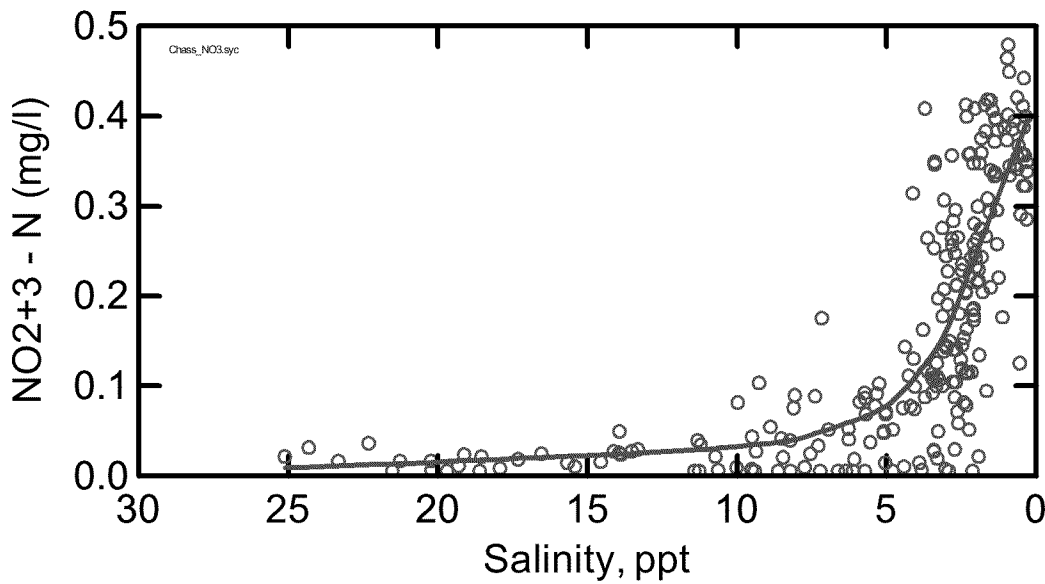


Figure 4-5 Relationship of salinity and nitrate in Chassahowitzka River

In order to determine if the nitrite/nitrate increase is related to flow of source water, the observed nitrate values at Main Spring were compared to the flow which existed on the sampling day. A LOWESS smooth (tension 0.5) was calculated and the variation in nitrate concentration not explained by flow (concentration residuals) was then correlated with time. Figure 4-6 illustrates a statistically significant relationship with time.

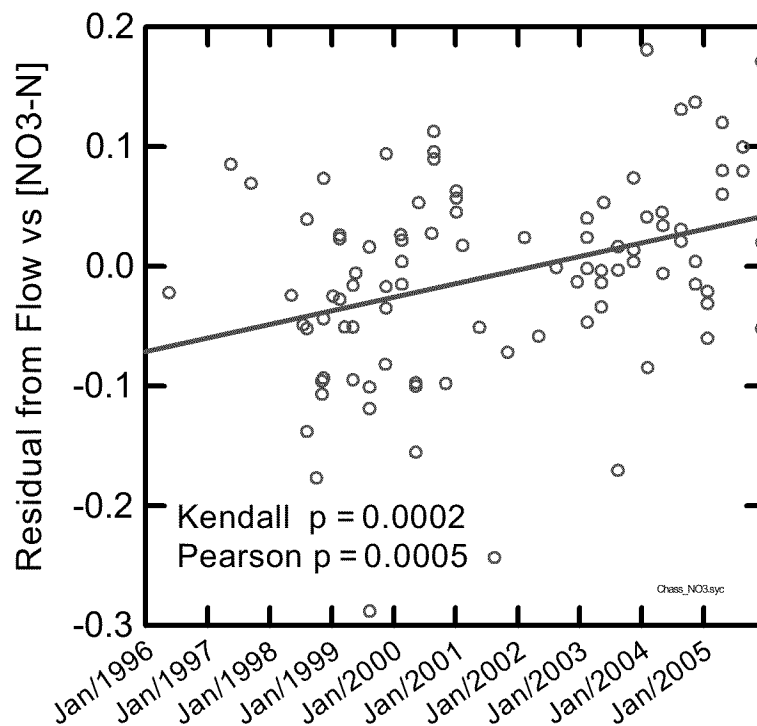


Figure 4-6 Residuals (Flow vs Nitrate) as function of time

Ground water discharging from springs often has low dissolved oxygen (less than 5 mg/l) (Frazer et al. 2001). Frazer cited the lowest average concentrations measured occurred at the upper most transect (Transect 1) and marsh and estuarine sampling locations. However, dissolved oxygen concentrations at Transect 1 averaged 6.1 mg/l, with only 16 percent of the observations at or below 5 mg/l. Dissolved oxygen concentrations were highest in the middle vegetated section of the river (Frazer et al. 2001). Also there was no significant relationship between discharge and dissolved oxygen ($r^2 = 0.02$). This indicates that low dissolved oxygen is not a major issue with the ground water discharges.

In general, the water of the Chassahowitzka River is clear, very slightly alkaline pH, essentially devoid of phosphorus, but rich in nitrogen. Due to the lack of phosphorus, primary productivity (as chlorophyll) is low resulting in oligotrophic conditions that affect the entire ecology. Water quality samples conducted by MML between 1996 and 2004 ((Dixon and Estevez, 2001) and unpublished raw data file dated 07/13/2007) were also assessed for the purposes of this MFL evaluation. The locations of the stations are depicted in Figure 4-7. Sampling parameters and statistics are provided in Table 4-3 The relationship of water quality to flow is included graphically in Appendix 7 for the Main Spring (MML station R0.0; Rkm = 8.8), the transition from upland to marsh (MML station R2.0; Rkm = 4.9) and at the MFL study boundary (MML station R4.0; Rkm = 0.4).

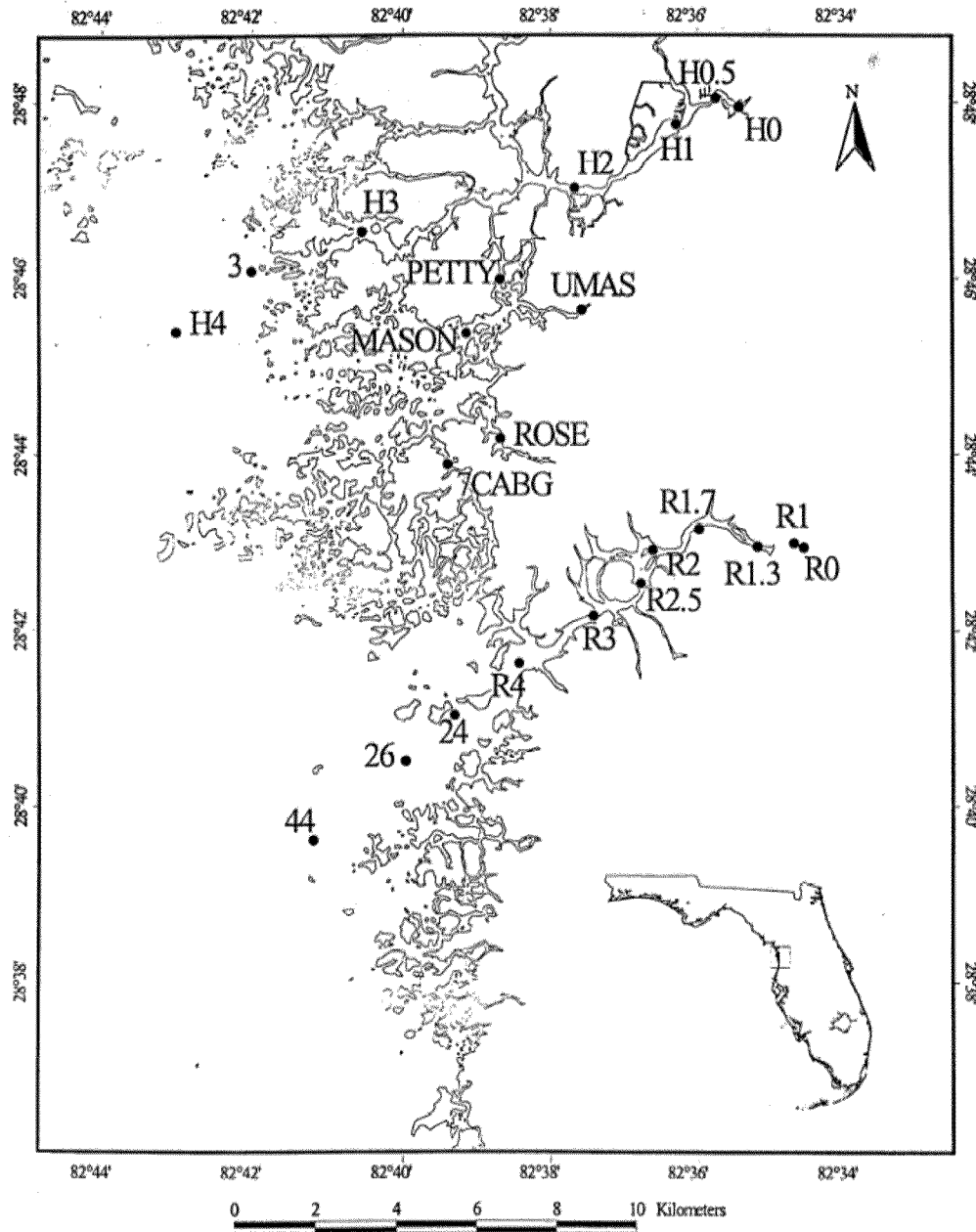


Figure 4-7 Water quality station locations (Dixon and Estevez 1998)

Table 4-3 Median water quality of Chassahotitzka River (1996-2004)

Station	Rkm (km)	Statistic	Sample Depth (m)	DO (mg/l)	Saturation of DO (%)	Specific Conductance (mmhos/cm)	Salinity (PSU)	Temp (C)	pH	Turbidity (NTU)	Color (PCU)	Color pH	TP mg/l)
R0.0	8.78	n	31	30	30	30	30	30	27	26	25	25	30
		median	0.20	6.28	73.9	1.67	0.87	23.34	7.74	0.7	6.0	7.88	0.05
R1.0	8.48	n	33	32	32	33	32	32	29	29	28	28	33
		median	0.20	7.78	92.4	2.73	1.47	23.79	7.88	1.2	7.0	8.03	0.05
R1.3	7.74	n	28	28	28	28	28	28	26	25	24	24	28
		median	0.20	10.42	122.7	3.82	2.03	24.15	8.23	1.2	10.0	8.36	0.05
R1.7	6.21	n	32	32	32	32	32	32	30	29	28	28	32
		median	0.20	8.86	103.9	4.75	2.67	24.70	7.91	1.9	16.0	8.08	0.05
R2.0	4.87	n	32	32	32	31	31	31	31	27	26	26	31
		median	0.20	6.41	77.9	5.07	2.76	24.50	7.67	2.5	22.5	7.95	0.05
R2.5	3.66	n	29	29	29	29	29	29	27	26	25	25	29
		median	0.20	6.01	82.3	9.78	5.53	25.40	7.76	2.8	36.0	8.05	0.05
R3.0	2.46	n	32	32	32	32	32	32	29	28	27	27	32
		median	0.20	6.02	84.1	11.49	6.51	25.75	7.82	2.3	36.0	8.03	0.05
R4.0	0.47	n	29	29	29	29	29	29	26	25	24	24	29
		median	0.20	6.38	84.5	16.22	9.48	25.94	7.78	2.1	34.5	8.05	0.05
24	-1.49	n	33	33	33	33	33	33	28	27	26	26	33
		median	0.20	6.54	91.6	23.27	14.03	26.99	7.94	2.3	26.5	8.18	0.05
Sampling and analysis conducted by Mote Marine Laboratory (Dixon and Estevez 2001 and unpublished data).													

Table 4-3 (Cont.)

Station	Rkm (km)	Statistic	PO4P (mg/l)	NH4N (mg/l)	NO23N (mg/l)	TKN (mg/l)	CHL_A (ug/l)	CHL_B (ug/l)	CHL_C (ug/l)	TSS (mg/l)	TN (mg/l)	Ratio TN:TP	IN (mg/l)
R0.0	8.78	n	30	30	30	30	14	14	14	4.0	30	30	30
		median	0.0175	0.005	0.380	0.08	1.4	0.5	0.5	2.0	0.437	16.7	0.399
R1.0	8.48	n	33	33	33	33	16	16	16	5.0	33	33	33
		median	0.016	0.005	0.349	0.05	3.5	0.5	0.5	2.0	0.384	14.8	0.360
R1.3	7.74	n	28	28	28	28	13	13	13	4.0	28	28	28
		median	0.014	0.010	0.263	0.09	1.9	0.5	0.5	2.5	0.351	12.0	0.271
R1.7	6.21	n	32	32	32	32	15	15	15	4.0	32	32	32
		median	0.010	0.012	0.1135	0.21	6.6	0.5	0.7	2.5	0.329	10.35	0.132
R2.0	4.87	n	31	31	31	31	15	15	15	4.0	31	31	31
		median	0.010	0.020	0.104	0.19	4.9	0.5	0.5	4.0	0.350	11.0	0.132
R2.5	3.66	n	29	29	29	29	13	13	13	5.0	29	29	29
		median	0.009	0.017	0.054	0.33	3.9	0.5	0.5	7.0	0.399	10.8	0.093
R3.0	2.46	n	32	32	32	32	15	15	15	5.0	32	32	32
		median	0.0085	0.015	0.041	0.35	3.5	0.5	0.5	6.0	0.384	12.15	0.064
R4.0	0.47	n	29	29	29	29	14	14	14	4.0	29	29	29
		median	0.007	0.014	0.021	0.33	2.45	0.5	0.5	4.0	0.370	9.7	0.046
24	-1.49	n	33	33	33	33	16	16	16	5.0	33	33	33
		median	0.005	0.009	0.005	0.42	2.2	0.5	0.6	4.0	0.423	10.1	0.016
Sampling and analysis conducted by Mote Marine Laboratory (Dixon and Estevez 2001 and unpublished data).													

CHAPTER 5 - BIOLOGICAL CHARACTERISTICS

5.1 Benthos

5.1.1 Descriptive (Adapted from Janicki Environmental 2006, Grabe and Janicki 2008)

The main channel of the Chassahowitzka River was surveyed during both the dry (May) and wet seasons (September) of 2005 for infaunal and SAV associated epifaunal macroinvertebrates by Mote Marine Laboratory and results analyzed by Janicki Environmental (2006). In 2008, six tributaries to the upper Chassahowitzka River were sampled for the purpose of determining if the benthic community within the tributaries was different from that observed in the main river (See Appendix 8 – Grabe and Janicki 2008).

A three inch (7.63 cm) diameter core sampler was used to collect the soft sediment infauna and a sweep net was used to collect SAV-associated epifauna. Fourteen cores and sweep nets samples were collected from the Chassahowitzka River and 35 samples were collected from the six tributaries (Table 5-1).

Table 5-1 Tributaries and river strata selected for the collection of benthic samples in the Chassahowitzka River and the number of samples collected, May 2005 and April 2008 (Janicki Environmental 2006, Grabe and Janicki 2008)

Tributary	Number of Samples Collected
Upper Chassahowitzka River (May 2005)	11
Crab Spring (April 2008)	6
Lettuce Spring (April 2008)	1
Crawford Creek (April 2008)	8
Baird Creek (April 2008)*	0
Salt Creek (April 2008)	8
Potter Creek (April 2008)	8
Ryle Creek (April 2008)	4
Lower Chassahowitzka River (May 2005)	3
Total	49
*Baird Creek was obstructed by a fallen tree and could not be sampled.	

Dominant taxa were identified for each tributary and the Upper Chassahowitzka and Lower Chassahowitzka rivers. Dominants are identified by their dominance score, which is calculated as:

$$\text{Dominance Score} = (\% \text{ occurrence} * \% \text{ composition})^{-0.5}.$$

The Dominants of the eight study areas were generally segregated into an upstream and a downstream group. The four more upstream creeks, northern shoreline systems (upstream of Rkm 6), and the Upper Chassahowitzka River had the estuarine amphipod *Grandidierella bonnieroides* as a Dominant. Oligochaete worms, which could represent

either freshwater and/or estuarine species, were also Dominant in the upper river, Crab, Lettuce, and Salt creeks—but not in Potter Creek (Table 5-2). Freshwater insect larvae were rarely included among the Dominants, except in the single Lettuce Creek sample (Grabe and Janicki 2008).

The Dominants in the Lower Chassahowitzka River and Crawford and Ryle creeks (downstream and southern shore) included estuarine *Ampelisca* spp. amphipods, and, in the two creeks, *G. bonnieroides* (Table 5-2) (Grabe and Janicki 2008). Using Analysis of Similarity (ANOSIM) found in PRIMER software (Clark and Warwick, 2001), Grabe and Janicki concluded that all of the tributary communities and significantly different from the benthic community in the upper river and Ryle Creek is significantly different from the other tributary communities.

Table 5-2 The top ten highest dominance score for macroinvertebrate taxa identified from infaunal samples collected in the Chassahowitzka River and six selected tributaries (Grabe and Janicki 2008)

TAXON	Lower River	Crab	Crawford	Lettuce	Potter	Ryle	Salt	Upper River
Athenaria	13							3
ANNELIDA								
Polychaeta								
<i>Heteromastus filiformis</i>						14		
<i>Hobsonia florida</i>		6		23				
<i>Laeonereis culveri</i>	15	43	15	16	17		12	22
<i>Leitoscoloplos robustus</i>						12		
Oligochaeta	30	42	24	45	37	15	51	49
Hirudinea				23	5			
MOLLUSCA								
<i>Acteocina canaliculata</i>						14		
Gastropoda			10			14		
<i>Littoridinops palustris</i>					12			
Bivalvia								
<i>Cyrenoida floridana</i>			14					
<i>Macoma tenta</i>			10			12		
CRUSTACEA								
Amphipoda								
<i>Americorophium ellisi</i>								
<i>Ampelisca vadorum</i>			40			61		
<i>Ampelisca</i> sp.	76							9
<i>Amphilocheus</i> sp.		4						
Corophiidae	18							33
<i>Gammarus mucronatus</i>	13	32	17	23	58	16	38	21
<i>Grandidierella bonnieroides</i>	17	44	44	48	47	46	46	38
<i>Melita</i> sp.	11							
<i>Monocorophium</i> sp.							6	
Isopoda								
<i>Cyathura polita</i>	11	24	10	16	9		8	16

<i>Edotea montosa</i>		16		16	13		8	
<i>Xenanthura brevitelson</i>	10					21		
Tanaidacea								
<i>Hargeria rapax</i> / <i>Leptochelia forresti</i>	11	23				26		12
Cumacea								
<i>Almyracuma bacescui</i>			12		8		17	3
INSECTA								
Trichoptera		4						
Diptera-Chironomidae								
<i>Cladotanytarsus</i>				39				
<i>Polypedilum scalaenum</i>		16		39	7		7	
<i>Procladius</i>				16				

5.1.2 Relation to Inflow

Quantitative relationships with inflow were not developed with the benthic results, although salinity was evaluated along with other physical-chemical parameters. Data from the upper and lower Chassahowitzka river (but not the tributaries), Weeki Wachee and Mud Rivers were pooled and several summary statistics developed (Janicki Environmental 2006). The 2005 data from the mainstem Chassahowitzka River (excluding the tributaries sampled in 2008) were extracted from the larger database and the relationship between salinity and richness (\log_{10} number of taxa +1), Shannon-Wiener diversity H' (using base 2) and total abundance (as \log_{10} number +1 per m^2) was re-evaluated as linear, quadratic and third order polynomial functions with salinity as the independent variable. Only the diversity relationships were significant at $p \leq 0.05$ and the quadratic and third order terms were not significant in the higher order relationships thus leaving the following relationship:

$$H' = 3.106 + 6.747 * \text{Salinity} \quad (n = 28, r^2 = 0.29, p = 0.002)$$

Since diversity increases with salinity, the relationship offers little value toward establishing withdrawal limits.

5.2 Fish

5.2.1 Descriptive (Adapted from Greenwood et al. 2008)

A two-year study of freshwater inflow effects on habitat use by estuarine organisms in the Chassahowitzka River estuary was undertaken from August 2005 to July 2007 (See Appendix 10 – Greenwood et al. 2008). The general objective of this data analysis was to identify patterns of estuarine habitat use and organism abundance under variable freshwater inflow conditions and to evaluate responses. Systematic monitoring was performed to develop a predictive capability for evaluating potential impacts of proposed freshwater withdrawals and, in the process, to contribute to baseline data. The predictive aspect involves development of regressions that describe variation in organism

distribution and abundance as a function of natural variation in inflows. These regressions can be applied to any proposed alterations of freshwater inflows that fall within the range of natural variation documented during the data collection period. For sampling purposes, the Chassahowitzka River estuary was divided into five zones from which plankton net, seine net and trawl samples were taken (Figure 5-1). Sampling was conducted on a monthly basis for the first year of the study (August 2005 to July 2006) and every six weeks for the remainder of the study (August 2006 to July 2007). Salinity, water temperature, dissolved oxygen and pH measurements were taken in association with each net deployment.

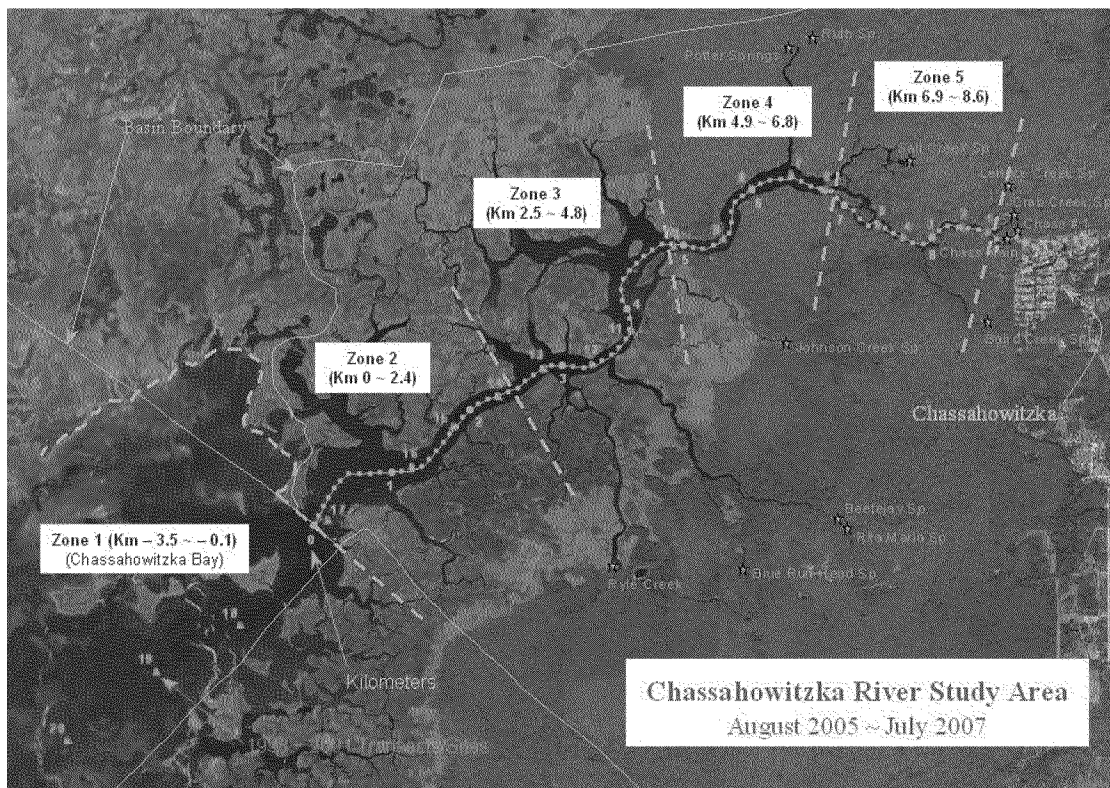


Figure 5-1 Map of the fish/invertebrate sampling zones

Three gear types were implemented to monitor organism distributions: a plankton net with a 0.02 inch (500 μ m) mesh deployed during nighttime flood tides; a bag seine with 0.126 inch mesh (3.2 mm); and otter trawl with 0.126 inch mesh deployed during the day under variable tide stages. The locations for seine and trawl deployment were randomly selected within each zone during each survey, whereas the plankton-net collections were made at fixed stations within each zone.

The small organisms collected at night by the plankton net represent a combination of the zooplankton and hyperbenthos communities. The faunal mixture present in the nighttime water column includes the planktonic eggs and larvae of fishes. Although fish eggs and larvae are the target catch, invertebrate plankton and hyperbenthos almost always dominate the samples numerically. The invertebrate catch largely consists of

organisms that serve as important food for juvenile estuary-dependent and estuarine-resident fishes.

Seines and trawls were used to survey larger organisms that typically evade plankton nets. Generally speaking, the data from seine hauls document habitat use by shallow-water organisms whereas the data from trawls document habitat use in deeper areas. The dominant catch for both gear types is juvenile fishes, although the adults of smaller species are also commonly caught. The seines and trawls also regularly collect a few of the larger macroinvertebrate species from tidal rivers, notably juvenile and adult blue crabs (*Callinectes sapidus*) and juvenile pink shrimp (*Farfantepenaeus duorarum*), as well as smaller invertebrates such as grass shrimp (*Palaemonetes* spp.).

The plankton net was towed behind a vessel in such a manner as to direct propeller turbulence away from the towed net. The boat towed the net along a nearly constant depth contour that was estimated to be close to the average cross-sectional depth for the local river reach. A flow meter measured volume sampled, which was typically on the order of 91-104 yd³. Plankton tows began within two hours after sunset and typically ended less than four hours later.

The bag seine was deployed along shoreline habitats (i.e., shorelines with water depth ≤5.9 feet in the Chassahowitzka River and bay) and in shallow waters (< 4.9 feet) of the bay zone. The area sampled was approximately 81 yd² in deeper water and 167 yd² in the shallows.

Trawling was conducted in the bay zone (zone 1), lowermost river zone (zone 2), and river zone 3. No trawling was conducted in the upper two zones due to unsuitable conditions. The approximate area sampled by a typical tow was 860 yd². Salinity, temperature, pH, and dissolved oxygen were measured at the surface and at 1-meter (3.3-foot) intervals to the bottom in association with each gear deployment.

5.2.1.1 Fish Composition

Larval gobies and anchovies dominated the plankton net's larval fish catch. *Gobiosoma* spp. and *Microgobius* spp. were the dominant goby taxa, and the anchovies were strongly dominated by the bay anchovy (*Anchoa mitchilli*). Other abundant larval fishes included silversides (*Menidia* spp.), rainwater killifish (*Lucania parva*), eucinostomus mojarra (*Eucinostomus* spp.), and blennies.

Over 90 percent of the seine catch was comprised of rainwater killifish, menidia silversides, bay anchovy, coastal shiner (*Notropis petersoni*), eucinostomus mojarra, pinfish (*Lagodon rhomboides*), bluefin killifish (*Lucania goodei*), tidewater mojarra (*Eucinostomus harengulus*), and goldspotted killifish (*Floridichthys carpio*). Fish collections from deeper, trawled areas were dominated by pinfish and eucinostomus mojarra. These taxa comprised over 58 percent of total trawl catch of fishes.

5.2.1.2 Invertebrate Composition

The plankton-net invertebrate catch was dominated by gammaridean amphipods, larval crabs (decapod zoeae and megalopae), cumaceans, the mysids *Americamysis almyra* and *Bowmaniella dissimilis*, prosobranch snails, and larval shrimps (decapod mysids). Riverplume-associated taxa, with the exception of the calanoid copepod *Acartia tonsa*, were less common than they typically are in more nutrient-rich estuarine plumes along the west-central Florida coast.

Invertebrates collected by seines were dominated by brackish grass shrimp (*Palaemonetes intermedius*), blue crab, and pink shrimp, which together comprised over 98 percent of total invertebrate catch in seines. Nearly 95 percent of the trawl catch was comprised of these same three species.

5.2.2 Relation to Inflow

Response to inflow was assessed in terms of location of maximum occurrence and in terms of quantity (abundance) of organisms present. The location metric is based on the mean location of the catch-per-unit-effort (CPUE) where the CPUE is the number of organisms per volume (plankton net) sampled or area sampled (seine or trawl). For simplicity CPUE is abbreviated as "U". The location metric is defined as:

$$kmu = \sum (km * U) / \sum U$$

where km is distance from river mouth.

The number of organisms collected is expressed in terms of either absolute or relative abundance (*N*). For plankton tows, the total number (*N*) of organisms was estimated by calculating the product of mean organism density (expressed as # / m³) and the volume of the river (corrected for tide stage at the time of capture). For the seine and trawl data, the relative abundance (*N*, #/ m²) was calculated for each month as:

$$N = 100 * N_{total} / A_{total}$$

where

*N*_{total} = total number of organisms capture that month, and

*A*_{total} = total area swept by the seine or trawl that month.

Inflow response regressions were developed for each of the gear types and both response metrics. For plankton net collections, location was used without transformation, but for the seine and trawl data, the location was natural log transformed after addition of "1.79" to adjust for negative values when taxa were centered below the mouth of the river. For seine and trawl results flow and relative abundance were natural log transformed (after addition of "1" to avoid censoring zero values). Plankton abundance and flow were natural log transformed without the addition of '1'. Mean flows were consecutively evaluated to find the maximum coefficient of determination. Ten linear and non-linear regression models were evaluated for each taxa captured in the plankton tows, while the seine and trawl results were subjected to linear and quadratic regressions models. Daily mean inflows extending as far back as 120 days were

evaluated for the plankton tow results. Mean flows from the date of sampling, as well as continuously lagged weekly averages from the day of sampling to 365 days before sampling were evaluated at seven day intervals (i.e., average discharge for sampling day and preceding six days; average flow for sampling day and preceding thirteen days) for the seine and trawl captures.

5.2.2.1 Distribution – Plankton Net

Nine (14 percent) of the 66 plankton-net taxa evaluated for distribution responses to freshwater inflow exhibited significant responses. Six of these were positive responses, wherein animals moved upstream as inflows increased (Table 5-3). The remaining three taxa demonstrated negative responses, moving downstream as freshwater flows increased. The time lags for these responses were highly variable, ranging from 1 to 74 days.

5.2.2.2 Distribution – Seine and Trawl

Five (10.9 percent) of the 46 seine- or trawl-caught pseudo-species evaluated for distributional responses to freshwater inflow exhibited significant responses for at least one lagged flow period. Four of the five pseudo-species moved upstream in response to decreasing inflow (negative response) whereas the fifth pseudo-species moved upstream in response to increased inflow (positive response) (Table 5-4). The change in centers of abundance ranged from 1.7 to 3.8 km and occurred over a relatively small inflow change (13 to 27 cfs). The lag period for four of the pseudo species were relatively short (< 21 days), while the remaining species had a moderately long (49-day) lag period.

Table 5-3 Plankton-net organism distribution (kmU) responses to mean freshwater inflow (LnF), ranked by linear regression slope

Other regression statistics are sample size (n), intercept (Int.), slope probability (P) and fit (r^2). D is the number of daily inflow values used to calculate mean freshwater inflow. None of the time series data appeared to be serially correlated (Durbin-Watson statistic, $p > 0.05$ for all taxa) (Greenwood et al. 2008).

Description	Common Name	n	Int.	Slope	P	r^2	D
<i>Parasterope pollex</i>	ostracod, seed shrimp	11	-119.803	29.851	0.0048	0.61	43
<i>Cyathura polita</i>	isopod	11	-87.352	22.371	0.0154	0.50	15
<i>polychaetes</i>	sand worms, tube worms	20	-47.680	12.162	0.0249	0.25	6
<i>pelecypods</i>	clams, mussels, oysters	16	-44.340	11.173	0.0432	0.56	4
<i>trichopteran larvae</i>	caddisflies	15	-37.573	10.765	0.0016	0.55	1
<i>Sarsiella zostericola</i>	ostracod, seed shrimp	13	-24.075	5.867	0.0300	0.36	42
<i>gastropods, opisthobranch</i>	sea slugs	15	39.239	-9.464	0.0007	0.60	2
<i>Gobiosoma spp. postflexion larvae</i>	gobies	12	39.937	-9.606	0.0479	0.34	2
<i>Lucania parva adults</i>	rainwater killifish	11	120.274	-28.283	0.0276	0.43	74

Table 5-4 Best-fit seine and trawl-based pseudo-species distrubutional (ln(kmU)) response to continuously lagged mean freshwater inflow (ln(inflow)) for the Chassahowitzka River

Degrees of freedom (df), intercept (Int.), slope (Slope), probability that the slope is significant (P), and fit (Adj. r^2) are provided. The number of days in the continuously-lagged mean inflow is represented by D. An "x" in DW indicates that the Durbin-Watson statistic was significant ($p < 0.05$), a possible indication that serial correlation was present (Greenwood et al. 2008).

Species	Common Name	Gear	Size (mm)	Period	df	Int.	Slope	P	Adj. r^2	DW	D
<i>Callinectes sapidus</i>	Blue crab	Trawl	0 to 30	Jan-Dec	19	4.352	-0.523	0.0488	0.15		1
<i>Fundulus seminolis</i>	Seminole killifish	Seine	0 to 999	Jan-Dec	10	4.295	-0.376	0.0308	0.33		1
<i>Lucania parva</i>	Rainwater killifish	Seine	0 to 999	Jan-Dec	19	5.044	-0.589	0.0461	0.15	x	49
<i>Poecilia latipinna</i>	Sailfin molly	Seine	0 to 30	Jan-Dec	9	6.554	-0.945	0.0210	0.40		21
<i>Mugil cephalus</i>	Striped mullet	Seine	0 to 999	Jan-Dec	7	-4.129	1.560	0.0349	0.42		7

5.2.2.3 Abundance – Plankton Net

Thirteen (20 percent) of the 66 plankton-net taxa evaluated for abundance relationships with freshwater inflow exhibited significant responses (Table 5-5)⁶. Negative responses were common, occurring in 10 of the 13 taxa; these are usually caused by elevated flows washing marine-derived taxa out of the survey area. Bay anchovy juveniles had a positive abundance response to inflow. This response had a relatively long lag of 106 days, which is more than twice the typical age of the bay anchovy juveniles themselves (approximately 40 days). During high inflow periods, the Chassahowitzka River estuary apparently becomes more attractive as nursery habitat for the bay anchovy, and the juveniles seek out the middle reaches of the tidal river, much as they do in more strongly surface-fed estuaries. The estuarine tanaid *Hargeria rapax* exhibited a similar pattern.

5.2.2.4 Abundance – Seine and Trawl

Twenty-three (50 percent) of the 46 pseudo-species analyzed from the seine and trawl catches had a significant abundance response to average inflow. Nine of these pseudo-species had linear responses and the remaining 14 demonstrated quadratic responses of abundance to inflow. Six of the linear responses (blue crab [seines and trawls], *Synodus foetens*, *Syngnathus scovelli*, tidewater mojarra, and pinfish) were negative such that abundance increased with decreasing inflow. The negative response in these pseudo-species most likely indicates an increase in the amount of slightly higher salinity habitats as flows decreased. Similarly, two of the three positive linear responses (bluefin killifish and spotted sunfish (*Lepomis punctatus*)) were observed for freshwater taxa that would be expected to move downstream with increases in inflow and subsequent increases in the amount of freshwater habitat. The most common quadratic response was an “intermediate-maximum” where the maximum abundance occurred at intermediate inflows and abundance was lower at both lower and higher inflows. The percentage of significant abundance responses to inflow ranged from 35.3 percent of tested pseudo-species in estuarine spawners to 85.7 percent in offshore spawners. Tidal river residents most commonly exhibited intermediate-maximum relationships to flow, while offshore spawners exhibited intermediate-maximum (3), negative (2), and intermediate-minimum (1) responses to inflow. All three of the nearshore spawners that had significant regressions demonstrated negative responses to flow.

Standard regression analyses typically correlate antecedent flow conditions with fisheries data aggregated over a sampling event. Often, these regressions rely on relatively small sample sizes. Data points that deviate largely from the average inflow or data points that have large residuals can overly influence the regression fit and calculation of the regression equation using ordinary least squares (OLS) regression. These overly influential data points include “outliers” and “leverage points.” Inspection of the graphic results presented by Greenwood et al. (2008) suggest that several of the regressions presented by these authors have outliers and high leverage data. Regressions using OLS that do not account for outliers and leverage points can result in lower statistical power, wider confidence intervals and/or biased prediction of the

⁶ Response of abundance to flow was evaluated using plankton net data censored to days of positive capture. There were no zero abundance results included in the evaluations.

response relationship leading to false inference with respect to the predicted effects of inflow reductions on fish responses (Wessel 2009).

Robust regression is a statistical technique used for the diagnosis of outliers and leverage points that can provide more stable parameter estimates compare to OLS regression in the presence of outliers. By using iteratively re-weighted least squares methods, robust regression can down-weight the effects of outliers to provide more robust prediction of relationships especially when datasets are of relatively small sample size (Wessel 2009). Therefore, robust regression techniques were applied to the seine and trawl data presented by Greenwood et al. (2008) to develop robust relationships between inflow and fish abundance responses for the MFL determination, where appropriate. Two taxa (*Opsanus beta* and *Strongylura timucu*) were omitted from the analysis due to their low sample size (n=8 and n=11, respectively). Additionally, the robust regression for *Fundulus seminolis* would not converge. Of the twenty-two species that were analyzed using the robust regression, nineteen had robust regressions that could be analyzed further (Table 5-6).

Table 5-5 Plankton-net organism abundance responses to mean freshwater inflow (Ln F), ranked by linear regression slope. Other regression statistics are sample size (n), intercept (Int.), slope probability (P) and fit (r^2). DW identifies where serial correlation is possible (x indicates $p < 0.05$ for Durbin-Watson statistic). D is the number of daily inflow values used to calculate mean freshwater inflow (Greenwood et al. 2008). Highlighted pseudo-species are those that met evaluation criteria.

Description	Common Name	n	Int.	Slope	P	r^2	DW	D
Anchoa mitchilli juveniles	bay anchovy	18	-52.561	15.666	0.0066	0.38	x	106
Hargeria rapax	tanoid	20	-22.269	8.521	0.0024	0.41		4
dipterans, chironomid larvae	midges	20	-16.140	7.029	0.0115	0.31		47
unidentified <i>Americamysis</i> juveniles	opossum shrimp, mysids	20	40.506	-5.959	0.0003	0.53		106
<i>Harrietta faxoni</i>	isopod	20	46.556	-8.190	0.0213	0.26		26
Cumaceans	cumaceans	20	55.616	-9.591	0.0361	0.22	x	5
Polychaetes	sand worms, tube worms	20	60.455	-11.705	0.0012	0.45		90
<i>Sarsiella zostericola</i>	ostracod, seed shrimp	13	61.622	-12.625	0.0033	0.56		2
gobiid flexion larva	gobies	14	76.866	-15.711	0.0098	0.44		104
<i>Pseudodiaptomus coronatus</i>	copepod	18	75.415	-15.879	0.0006	0.53		2
<i>Acartia tonsa</i>	copepod	20	82.060	-16.877	0.0035	0.39		93
<i>Parasterope pollex</i>	ostracod, seed shrimp	11	78.838	-16.922	0.0022	0.67		14
<i>Microgobius</i> spp. postflexion larvae	gobies	15	91.591	-19.607	0.0019	0.54		115

Table 5-6 Best-fit seine and trawl-based pseudo-species abundance (N+1) response to continuously-lagged mean freshwater inflow (Ln F+1) for the Chassahowitzka River estuary from the robust regression analysis (Wessel 2009).

The type of response (Resp.) is either linear (L) or quadratic (Q). Degrees of freedom (df), intercept (Int.), slope (Linear Coef.), probability that the slope is significant (Linear P), quadratic coefficient (Quad. Coef.), probability that the quadratic coefficient is significant (Quad. P) and fit (Adj. r^2) are provided. The number of days in the continuously-lagged mean inflow is represented by D. An "x" in DW indicates that the Durbin-Watson statistic was significant ($p < 0.05$), a possible indication that serial correlation was present (Greenwood et al. 2008). Highlighted pseudo-species are those that met evaluation criteria. Robust regression parameters from Wessel (2009)

Species	Common Name	Gear ⁷	Size (mm)	Period	Resp.	df	Int.	Linear Coef.	P	Quadratic Coef.	P	Adj. r^2	DW	D
Farfantepenaeus duorarum	Pink shrimp	S	0 to 30	Jan-Dec	Q	18	-1241.53	610.89	0.0333	-75.07	0.0323	0.42	x	126
Farfantepenaeus duorarum	Pink shrimp	T	0 to 30	Jan-Dec	Q	18	-377.15	184.94	0.0008	-22.65	0.0007	0.37		182
Callinectes sapidus	Blue crab	S	0 to 30	Sep-Mar	L	10	39.08	-9.00	0.0024	-	-	0.52		231
Callinectes sapidus	Blue crab	T	0 to 30	Jan-Dec	L	19	2.77	-0.58	0.6452	-	-	0.20	x	168
Anchoa mitchilli	Bay Anchovy	S	31 to 50	Jan-Dec	Q	18	708.83	-352.00	0.0398	43.70	0.0372	0.39		28
Synodus foetens	Inshore lizardfish	T	0 to 130	May-Jan	L	14	3.63	-0.85	0.0087	-	-	0.44	x	1
Fundulus grandis	Gulf killifish	S	51 to 100	Jan-Dec	Q	18	-2127.11	1038.40	0.0127	-126.63	0.0126	0.36		259
Lucania parva	Rainwater killifish	S	0 to 999	Jan-Dec	Q	18	-2372.39	1157.57	0.0001	-140.96	0.0001	0.57	x	168
Lucania goodei	Bluefin killifish	S	0 to 50	May-Nov	L	11	-67.45	16.95	0.0032	-	-	0.55	x	175
Poecilia latipinna	Sailfin molly	S	31 to 999	Jan-Dec	Q	18	-593.84	290.45	0.0076	-35.49	0.0075	0.40		189
Syngnathus scovelli	Gulf pipefish	T	0 to 130	Jan-Dec	L	19	3.45	-0.79	0.0200	-	-	0.17	x	364
Lepomis punctatus	Spotted sunfish	S	0 to 100	May-Nov	L	11	-31.05	7.82	0.0001	-	-	0.59		21
Eucinostomus harengulus	Tidewater mojarra	S	40 to 999	Jan-Dec	L	19	29.78	-6.92	0.0034	-	-	0.39	x	1

⁷ Gear type: S = seine, T= Trawl

Lagodon rhomboides	Pinfish	S	0 to 50	Jan-Jun	Q	8	-3168.89	1561.57	0.0001	-192.13	0.0001	0.74	x	98
Lagodon rhomboides	Pinfish	S	51 to 100	Apr-Sep	L	8	30.13	-6.86	0.0442	-	-	0.48		168
Mugil cephalus	Striped mullet	S	0 to 999	Jan-Apr	Q	4	1582.16	-768.81	0.0001	93.39	0.0001	0.94	x	1
Microgobius gulosus	Clown goby	S	0 to 30	Jan-Dec	Q	18	-1902.09	930.84	0.0087	-113.79	0.0087	0.30		168
Microgobius gulosus	Clown goby	S	31 to 50	Jan-Dec	Q	18	-775.58	380.18	0.0018	-46.53	0.0018	0.47		56
Trinectes maculatus	Hogchoker	S	0 to 999	Jan-Dec	Q	18	-483.80	236.31	0.0719	-28.83	0.0713	0.27	x	280

5.3 Mollusk

5.3.1 Descriptive

During 2007, Estevez conducted a mollusk survey of the Chassahowitzka using rapid survey techniques described by Estevez (2007) (See Appendix 11) and as applied to other tidal rivers along the west coast of Florida. The Chassahowitzka River was sampled from its mouth to Rkm 9.5 on one-kilometer intervals from Rkm 0-5 and at half-kilometer intervals from Rkm 5 to Rkm 9.5. Both live and dead material was quantified.

Species richness was low, with a total of 13 taxa collected (Table 5-7). By comparison, richness for other systems sampled using similar techniques are 34 in both the Peace and Dona/Roberts Bay systems, 24 in the Myakka, 20 in the Alafia, and 11 in Shell Creek (Estevez 2007).

Table 5-7 Rank and order abundance of mollusk species in the Chassahowitzka River (Estevez 2007)

Species	Count	Abundance (#/m ²)	Percent	Cumulative Percent
<i>Crassostrea virginica</i>	201	115.52	44.37	44.37
<i>Polymesoda caroliniana</i>	73	41.95	16.11	60.49
<i>Ischadium recurvum</i>	67	38.51	14.79	75.28
<i>Bivalvia</i> juv.	36	20.69	7.95	83.22
Hydrobiidae	25	14.37	5.52	88.74
<i>Corbicula fluminea</i>	23	13.22	5.08	93.82
<i>Neritina usnea</i>	9	5.17	1.99	95.81
<i>Tagelus plebeius</i>	9	5.17	1.99	97.79
<i>Geukensia demissa</i>	3	1.72	0.66	98.45
<i>Boonea</i> cf. <i>impressa</i>	2	1.15	0.44	98.90
<i>Macoma constricta</i>	2	1.15	0.44	99.34
<i>Melongena corona</i>	2	1.15	0.44	99.78
<i>Pomacea paludosa</i>	1	0.57	0.22	100.00
Total	453	260	100	
Note: Each of the 15 total transects had a sampling area of 0.116 m ² . Total number of individuals observed includes both live and dead.				

The mollusk fauna of the Chassahowitzka is similar to that of other studied streams in terms of their overall species composition, but the Chassahowitzka River's fauna is reduced in diversity because marine influences do not extend from the Gulf of Mexico into the river. In terms of species abundance, the American oyster, *Crassostrea virginica*, was the most common native species. As depicted in Table 5-7, oysters were common in comparison to other species but this rank is an artifact of their high numbers in reefs near the river's mouth. Only two taxa of mussels were collected, which is relatively low species richness for mussels compared to other rivers. Two other intertidal species, *Polymesoda caroliniana* and *Neritina usnea* also were common. Live and dead *Corbicula* were found at the upstream-most stations. Compared to *Corbicula* in other rivers, the Chassahowitzka River specimens were small.

5.3.2 Relation to Inflow

The mollusk survey of the Chassahowitzka River was conducted on March 27 and 28, 2007 (Estevez 2007). To date, the mollusk surveys done along the west coast of Florida have been one- or two-day events per river. Thus, there has been no attempt to sample across a range of stream flows. Montagna (2006, Montagna et al. 2008) using data from the Peace, Myakka, Alafia, Weeki Wachee / Mud rivers, Shell Creek and Dona/Robert's Bay (but not the Chassahowitzka) identified several species that characterize a particular salinity zone. He went on to conclude:

"In this limited analysis of southwest Florida mollusk communities, it is concluded that mollusk species are controlled more by water quality rather than the sediment they live in or on. The most important variable correlated with mollusk communities is salinity, which is a proxy for freshwater inflow. It is impossible to directly link community changes in response to inflow changes, because no(t) replicates over time were carried out in the rivers sampled. Although total mollusk abundance was not a good indicator of inflow effects, certain indicator species have been identified however, that characterize salinity ranges in southwest Florida rivers."

The most common mollusks observed by Montagna are included in Table 5-8 and compared to the community observed in the Chassahowitzka River by Estevez (2007). Montagna found a number of significant relationships between abundance and salinity, which can be expressed as:

$$y = a * \exp(-0.5 * (\ln(x/x_0)/b)^2)$$

where

y = Number of organisms/m²

a = maximum abundance

x = salinity (ppt)

x₀ = salinity at maximum abundance

b = rate of response change

The model assumes that there is an optimal range for salinity and that values will decline in a non-linear fashion for salinities on either side of optimal (Montagna et al. 2002). Example responses from Florida Gulf samples identified by Montagna (2006) for the three most abundant taxa (*C. virginica*, *P. caroliniana* and *I. recurvum*) identified in the Chassahowitzka by Estevez are shown in Figure 5-2. Since the Chassahowitzka results were not included in Montagna's regional evaluation, an attempt to recreate similar optimal salinity models using the Chassahowitzka River data was undertaken. The results were unsuccessful. Only the *C. virginica* model was statistically significant (p=0.03). Figure 5-3, which shows *C. virginica* abundances at 15 transect sites in the Chassahowitzka River along with modeled salinity at the sites based on the 63 cfs median flow for the 1967-2007 reference period used for this minimum flows analysis suggests that the relatively low salinity areas sampled in the short, confined estuary may not have been adequate for characterization of oyster abundance within the

system. Montagna (2006) identified an optimal salinity range of 20 to 25 ppt for *C. virginica* in other area rivers and Volety *et al.* (2003), as cited in Barnes *et al.* (2007) reports a salinity optima for the species in the range of 14-28 ppt for southwest Florida rivers. Sites sampled on the Chassahowitzka River did not include downstream areas where these salinities may have occurred.

Table 5-8 Rank mollusk abundance - Florida West Coast Tidal rivers (Montagna 2006) and the Chassahowitzka River (Estevez 2007)

Percent Composition of Community Abundance		
Taxa	Rivers* (Montagna 2006)	Chass (Estevez 2007)
<i>Corbicula fluminea</i>	40.4	5.08
<i>Polymesoda caroliniana</i>	11.1	16.11
<i>Rangia cuneata</i>	8.0	0
<i>Tagelus plebeius</i>	5.6	1.99
<i>Amygdalum papyrium</i>	5.2	0
<i>Neritina usnea</i>	3.7	1.99
<i>Geukensia demissa</i>	3.4	0.66
<i>Tellina versicolor</i>	3.3	0
<i>Crassostrea virginica</i>	3.2	44.37
<i>Macoma constricta</i>	3.2	0.44
<i>Ischadium recurvum</i>	2.2	14.79
<i>Littoraria irrorata</i>	2.2	0
<i>Mulinia lateralis</i>	2.1	0
<i>Nassarius vibex</i>	1.7	0
Total	95.0	85.0

* Includes data from the Peace, Myakka, Alafia, Weeki Wachee/Mud Rivers, Shell Creek and Dona/Robert's Bay.

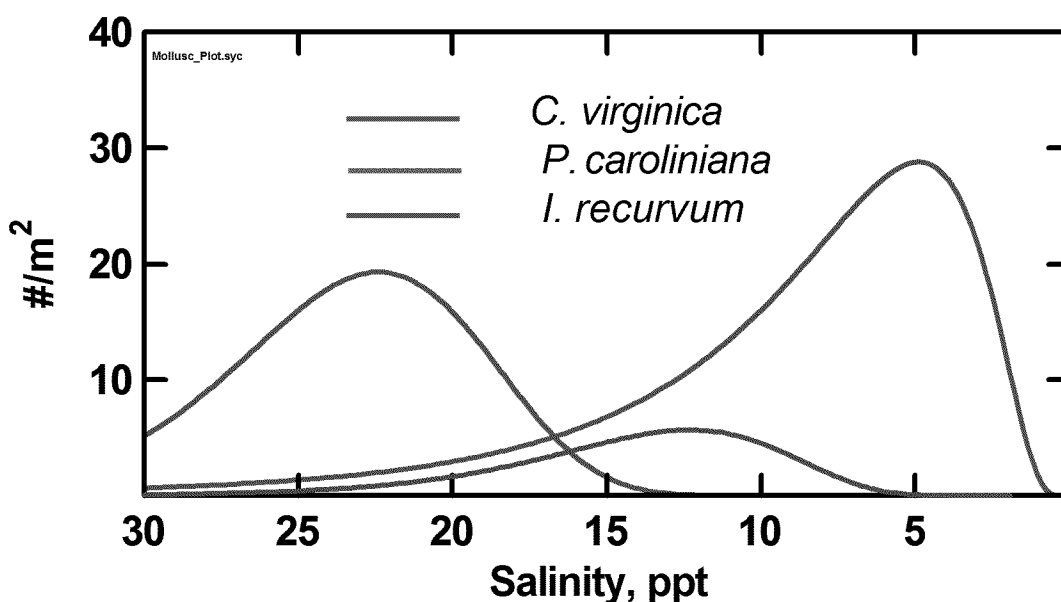


Figure 5-2 Regional salinity for three abundant molluscs found in the Chassahowitzka river (Mongagna 2006). Note - Data from the Chassahowitzka not included in the regional models.

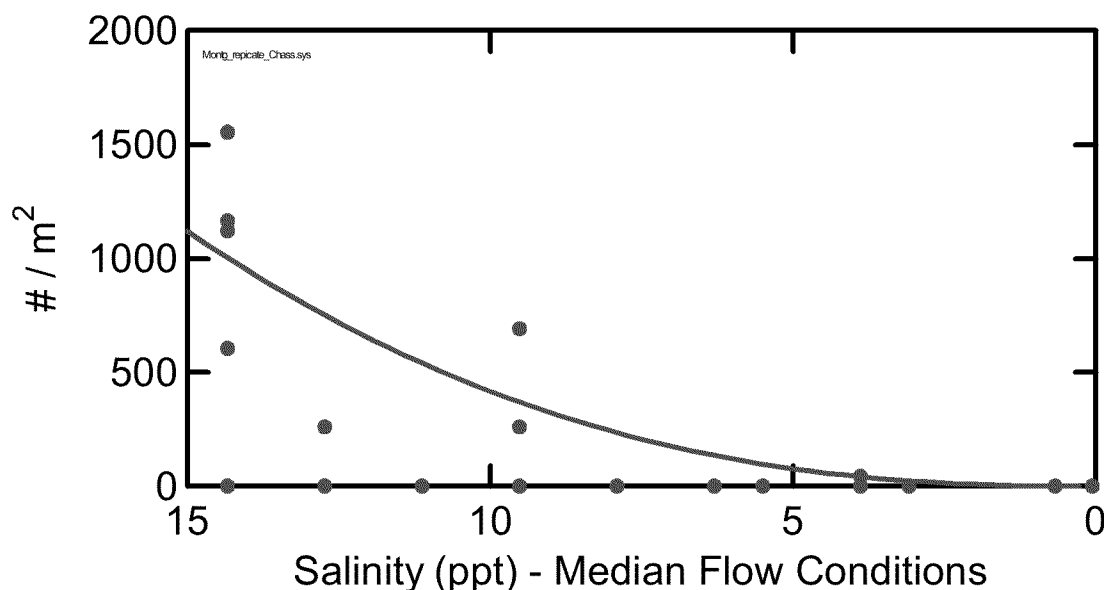


Figure 5-3 *C. virginia* abundance as function of salinity - Chassahowitzka River. (Results are individual ponar measurements)

5.4 Manatee

5.4.1 Descriptive (Adapted from Laist and Reynolds (2005))

The Florida manatee (*Trichechus manatus latirostris*) is a marine mammal subspecies of the West Indian manatee and is found only in the southeastern United States. The U.S. Fish and Wildlife Service (USFWS 2001) estimates a Florida population of around 3,276 animals based on a Florida-wide count during January 5-6, 2001. A subpopulation of approximately 400 animals is associated with the springs north of Tampa Bay.

Many animals succumb annually to collisions with boats and from the effects of a suite of neurotoxins (brevetoxins) produced by the red-tide dinoflagellate *Karenia brevis*. The Florida manatee is federally classified as an 'endangered' species, but on April 9, 2007 the U.S. Fish and Wildlife Service recommended⁸ that the designation be reduced from endangered to 'threatened'.

Manatees are poor thermal regulators. Animals exhibit a high degree of thermal conductance (poor insulation) with relatively low metabolic rates (Rouhani et al. 2006) and are generally vulnerable to exposure to temperatures below 68°F, although some animals can survive chronic exposure to temperatures a few degrees lower. In order to survive cold weather, manatees tend to congregate in warm water natural springs or in the cooling water discharge of power plants scattered along the coast of Florida. In developing the Blue Springs minimum flow regime, St.

⁸. <http://www.fws.gov/southeast/news/2007/r07-057.html>

John's Water Management District (SJRWMD) established a critical duration of 4-79 days for exposure at 20°C with return frequency of 50 years (long life span of a manatee). [The return interval is estimated as the joint probability product of discharge, temperature, and stage]. The potential loss of the artificial sources of warm water through plant closing and reduction of natural springflow due to groundwater withdrawals is of concern to the Warm-Water Task Force (a subcommittee of the Florida Manatee Recovery Team). Evidence suggests that the location and use of warm-water refuges is a response that calves learn from their mothers and thus the potential loss of a refuge can affect generations of manatees (Worthy 2005)

The USFWS conducts routine (approximately biweekly) aerial surveys along the west coast of Florida, but the Chassahowitzka River is infrequently included in those surveys. The results vary widely by survey with an average daily count of 182 animals with a standard deviation (sd) of 80 animals. Table 5-9 and Figure 5-4 provide the number of annual surveys by refuge area and Figure 5-5 illustrates the average number of animals by refuge. The area of heaviest use is King's Bay which averages 114 animals (std. dev. = 80) per aerial survey which represents sixty three percent of all animals counted over the past eleven years. In contrast, the Chassahowitzka has averaged only seven animals per survey during the same period. The maximum number of manatees counted in the Chassahowitzka was 48 animals recorded on May 7, 1996. Manatee usage appears heaviest in the spring (average 13.8 animals/survey for April, May and June) and minimal in the winter (Jan =0.1, Feb = 1.2 animals). No manatee surveys have been conducted in the Chassahowitzka during September through December).

Some of the difference results from the disparity in number of surveys per year, but when only the surveys that included Chassahowitzka are compared, the number of animals using Chassahowitzka averages four percent of the total animals counted.

It should be noted that local residents familiar with the river feel that the USFWS results underestimate the number of animals utilizing the Chassahowitzka River. (Verbal comments received at Pubic Workshop for proposed minimum flow of the Chassahowitzka River held on 10/06/2010 in Brooksville, Florida)

5.4.2 Relation to inflow

The primary relationship between flow and the health of the manatee is a function of providing a thermal refuge during extreme cold.

⁹ It should be noted that the SJRWMD evaluation used a more conservative three days for establishment of a minimum flow regime.

Table 5-9 Average number of surveys and manatee counts - Florida West Coast 1996-2005.

Year	Total	KB	CRY	UHOM	LHOM	SR	PP	BC	WAC	WIT	SWR	SRE	CH	WW
Average Number of Manatee / Survey														
2006	167	99	9	24	9	9	13	1	2	1	1	4	2	19
2005	157	99	8	29	6	2	11	0	1	0	2	0	5	14
2004	171	103	6	38	5	3	14	1	1	0	7	0	4	5
2003	187	127	7	34	3	2	10	0	1	0	2	0	5	5
2002	211	141	5	46	4	1	11	1	1	3	6	33	3	16
2001	176	121	5	37	4	2	13	1	0	6	6	0	5	13
2000	216	132	8	40	5	2	17	1	3	2	6	10	7	12
1999	222	133	6	51	6	1	23	0	0	1	6	0	2	12
1998	141	86	5	35	6	4	2	0	7	2	1	8	12	9
1997	158	99	6	30	6	4	7	1	3	1	2	3	13	2
1996	186	120	8	33	7	6	11	0	0	0	0	5	14	3
Overall	182	114	7	36	5	3	12	1	2	1	3	4	7	10
Average Number of Surveys / Year														
2006	16	16	16	16	16	16	16	15	2	2	2	2	3	3
2005	25	25	25	25	25	25	25	24	2	2	2	2	2	2
2004	27	27	27	27	27	27	27	27	2	2	2	2	2	2
2003	18	18	18	18	18	18	17	18	6	6	6	6	6	6
2002	22	22	22	22	22	22	22	22	2	2	1	1	1	1
2001	19	18	18	18	18	18	18	19	2	3	2	2	2	2
2000	28	28	28	28	28	28	28	28	6	7	7	7	7	7
1999	24	24	24	24	24	24	23	23	3	3	4	3	5	3
1998	22	22	22	22	22	22	22	22	1	1	2	1	2	2
1997	26	26	26	26	26	26	26	24	5	5	6	5	8	1
1996	23	23	23	23	23	23	22	22	3	3	3	3	4	2
Overall	23	23	23	23	23	23	22	22	3	3	3	3	4	3

KB = King's Bay / CRY = Crystal River / UHOM = Upper Homosassa River / LHOM = Lower Homosassa River / SR = Salt River
 PP = Crystal River Power Plant / WAC = Wacasassa / WIT = Withlacoochee / BC = Barge Canal / SWR = Suwannee River
 SWE = Suwannee River Estuary / CH = Chassahowitzka River / WW = Weeki Wachee River

Mantee Counts.xls

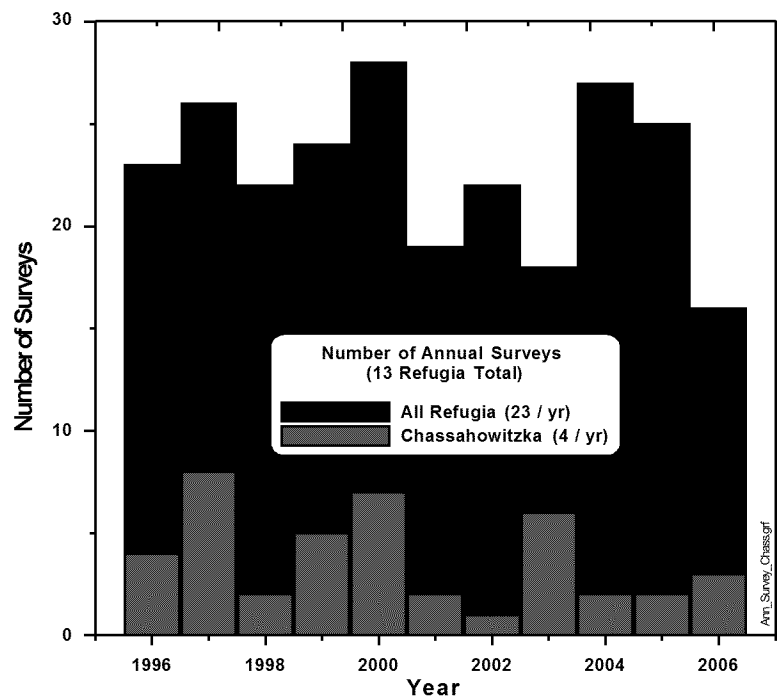


Figure 5-4 Number of aerial manatee surveys by year and refuge

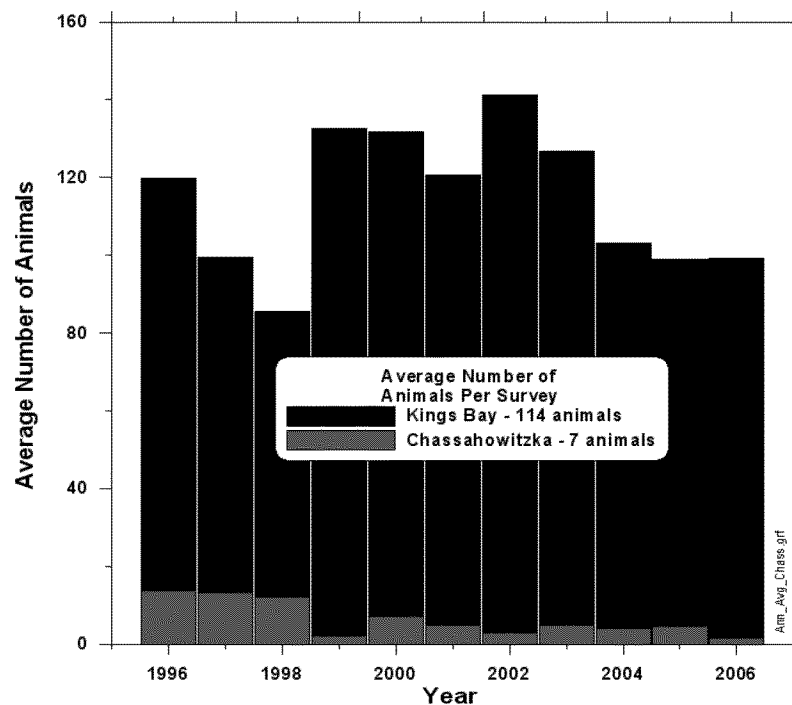


Figure 5-5 Average annual number of manatees - Chassahowitzka and King's Bay

CHAPTER 6 - CRITERIA FOR RESOURCES OF CONCERN

6.1 Resource Criteria / Goals

Evaluation criteria were established for salinity habitat, fish and invertebrates, and benthos using historic flow (e.g., observed record), since many of these tools were based on existing conditions and/or maximums. It acknowledged that a broad range of estuarine processes shape the biological responses. The authors acknowledge that salinity, expressed as an area, volume, or shoreline length of habitat, is a surrogate for wide variety of unquantified but important processes at work in the estuary.

6.1.1 Mollusc

Mollusc were not further evaluated because only *C. virginica* exhibited a statistically significant response to salinity but the sampling domain did not capture peak abundance for this taxa. Simulating withdrawal of freshwater would lead to prediction of increased abundance of this tax. No MFL criterion was established for the mollusc community.

6.1.2 Fish & Invertebrates

Regression criteria for evaluation included a) minimum 10 observations per variable, b) positive linear or 'mid-flow maximum abundance' quadratic response and adjusted r^2 of at least 0.3. As discussed in Section 5.2.2, the plankton net collection resulted in three positive flow responses for taxa abundance. The results (See Table 5-7) were identified as resources warranting further evaluation. The taxa included bay anchovy (*Anchoa mitchilli* juveniles), tanaid (*Hargeria rapax*), and midges (dipterans, chironomid larvae). In addition, six taxa from the seine and trawl results with the strongest positive abundance/flow responses and meeting the criteria above were also chosen for further evaluation. Two exhibited a linear response and include bluefin killifish and spotted sunfish. In addition pink shrimp, rainwater killifish, pinfish, and *Poecilia latipinna* (sailfin molly) exhibited mid flow maximum abundance and were evaluated. The 'significant harm' criterion was presumed to be met when flow reductions resulted in a 15 percent loss of abundance (linear) or peak abundance (quadratic response)

6.1.3 Submerged Aquatic Vegetation

Resource criterion for native SAV was based on an allowable increase in salinity at the location of maximum observed density reported recently by Mote Marine Laboratory (Leverone 2006). An estimate of the long-term salinity was developed from the LSM and is provided in Table 6-1. *Ruppia maritima* has a high tolerance to salinity and as such, it is not a strong indicator species.

Table 6-1 Dominant SAV - Location of maximum density and expected salinities (adapted from Leverone 2006)

Species	Baseline Flow (cfs)	Maximum Density (M.D.)	Rkm @ M.D.	Salinity @ M.D. (ppt)	Salinity Tolerance* (ppt)
<i>Vallisneria americana</i>	63	3.8	7	3.08	0-9
<i>Najas guadalupensis</i>	63	3.3	7	3.08	1-15
<i>Potamogeton pectinatus</i>	63	2.9	7.5	2.28	0-9
<i>Ruppia maritima</i>	63	2.8	3.5	8.71	2-70
* http://www.biology.lsu.edu/webfac/lurbatsch/seagrasses.html					

6.1.4 Benthos

Broad community response to salinity habitat has been demonstrated both regionally and for the mainstem Chassahowitzka River. However, the only statistically significant relationship obtained with the Chassahowitzka benthic data was for diversity and salinity. This relationship is positive, and thus decreasing flow will increase salinity – which will in turn increase the diversity. Thus, no MFL criterion was established for the benthic community.

6.1.5 Salinity Habitat Criteria

At the more general level, benthos habitat was evaluated in terms of bottom area in contact with a specified salinity and fish habitat was broadly evaluated as the volume of water at, or below some specified salinity. Isohaline values of 2, 5, 10 and 15 ppt were chosen for evaluation and a significant loss of habitat was defined as greater than a fifteen percent loss compared to the baseline. The salinity habitat criterion is derived from the findings reported by Dynamic Solutions, LLC (2009) (See Section 3.1.2). Dynamic Solutions, LLC developed a hydrodynamic model of the Chassahowitzka River and determined salinity changes and changes in the volume and area due to reductions in spring flow. The salinity habitat criterion was based on maximum flow reduction, defined as a flow that resulted in a 15 percent loss of habitat (i.e., volume, area and shoreline). Volume and area relationships were investigated using regressions, but the higher-order polynomial equations required precluded adequate smoothing, so the results were taken directly from hydrodynamic and hydrologic model output.

In addition to salinity volume and bottom habitats, the cumulative shoreline in contact with 2, 5, 10 and 15 ppt salinity was quantified and the flow reduction resulting in a 15 percent loss of shoreline length at those salinities was determined using the hydrodynamic model results.

6.1.6 Manatee Thermal Refuge Criteria

Manatees cannot tolerate more than four days of water at 68°F (chronic criteria) or more than four hours at 59°F (acute criteria) and must be able to access warm water. For the purpose of this evaluation, the following criteria were established (Rouhani et al. 2006, Dynamic Solutions LLC 2009,)

Chronic

- ☐ Minimum depth of water at low tide = 3.8 feet
- ☐ Refuge is accessible at high tide. Minimum high tide depth > 3.8 feet
- ☐ Must remain $\geq 68^{\circ}\text{F}$ for duration of critically cold three day period.

Acute

- ☐ Minimum depth of water at low tide = 3.8 feet
- ☐ Refuge is accessible at high tide. Minimum high tide depth ≥ 3.8 feet .
- ☐ The temperature cannot be $\leq 59^{\circ}\text{F}$ four or more hours.

While high tide is necessary to access some areas of the refuge, the higher tides drive the colder Gulf water further upstream. A combination of cold temperature and high tide conditions was selected with a return interval of 50 years (average life expectancy of Florida manatee) to represent the critically cold period. Details can be found in Appendix 13 (Dynamic Solutions LLC 2009). The significant harm threshold established was no more than a 15 percent loss of refuge volume meeting the above criteria under the critically cold conditions.

CHAPTER 7 - TECHNICAL APPROACH

7.1 Fish / Invertebrate Technical Approach

The fish and invertebrate resource response to flow was in general evaluated using the following equation from the robust regression analysis of seine / trawl data (See Table 5-6):

$$\ln(\text{Abundance}+1) = \text{Interception} + \text{Coef.}_{\text{linear}} * \ln(\text{Lag_Flow}+1) + \text{Coef.}_{\text{quadratic}} * [\ln(\text{Lag_Flow}+1)]^2$$

where, Abundance is expressed as catch per unit effort / 100 m².
(Linear response evaluated by setting Coef._quadratic to zero).

The response of smaller organisms captured in the plankton net was evaluated using the following equation (See Table 5-5)

$$(\text{Abundance}) = \text{Interception} + \text{Coef.}_{\text{linear}} * \ln(\text{Lag_Flow})$$

where, Abundance is expressed in units of total number in channel.

The abundance was then reduced by fifteen percent and the flow associated with the reduced abundance was back calculated. For *Anchoa mitchilli* juveniles, *Hargeria rapax*, and dipterans/chironomid larvae (positive plankton net results), eighty-five percent of the baseline abundance is predicted to occur at reduced flows of 62.3 (1.0 percent), 61.8 (1.9 percent), and 61.6 (2.3 percent) cfs respectively (Table 7-1).

For *Lucania goodei* and *Lepomis punctatus* (positive seine and trawl results) the reduced abundances are predicted to occur at reduced flows of 62.42 (0.9 percent) and 62.00 (1.6 percent) cfs respectively (Table 7-1).

These very sensitive responses to changes in flow identified for the five previous taxa are suspect when considering that the flow coefficient of variation (cv) for the actual 61 days of sampling was 11 percent and the cv of the entire sample period (August 2005 through August 2007) was also 11 percent. Put in perspective, and using the above relationship, the abundance of *A. mitchilli* at an 11 percent decrease in flow results in loss of 84 percent of the abundance.

Additional concerns about the reasonableness of the results became apparent when the criteria were applied to the flow / abundance relationships for *L. goodei* and *L. punctatus* (< 101 mm). As shown in Figure 7-1, when the flow (21 day moving average corresponding to the lag term in the regression) is reduced 15 percent to 53.6 cfs, the predicted response is the total elimination of *L. punctatus* from the Chassahowitzka River system. Twenty-one day average flows equal to, or less than this value occur 1,675 times in the baseline flow record. A similar calculation for *L. goodie* (based on a 175 day average flow of 54.7 cfs) indicates this taxa would have been 95 percent extirpated from the system 2,156 times in the past. Both of these reduced flows fall within the normal

variability of the system (Mean \pm 2 sd = 46 to 79 cfs) suggesting that perhaps flow is not the factor controlling the abundance of these organisms in the Chassahowitzka system.

It should be noted that the *L. goodie*, and *L. punctatus* and response curves were based on data collected only during May to November. The season flow variation in the Chassahowitzka River is minimal and further sub-setting the results to seasons constricts the range of the flow domain even further. In the case of *L. goodie* this is partially offset by the long lag (175 days) incorporated into the flow term, but in the case of *L. punctatus* the lag is only 21 days. In contrast, the results for *L. rhomboides* were also based on a limited season (January to June), but this taxa did not exhibit the type of hypersensitivity to flow reductions as *L. goodie* or *L. punctatus*. In consideration of the constancy of flow in the Chassahowitzka, seasonally variable MFLs are not appropriate for this system. Results based on seasonal catch results (e.g. *L. goodie*, *L. punctatus* and *L. rhomboides*) were not considered in the final determination of the MFL.

Table 7-1 provides the abundance, reduced abundance, reduced flow and percent of flow reduction resulting in a 15 percent change in abundance for all taxa that met the general regression criteria specified in Section 1.4.2 and were either a) positive linear response to flow, or exhibited mid-flow maximum for quadratic responses. (These taxa were introduced as highlighted rows in Tables 5-5 and 5-6.) Also included in Table 7-1 is a listing and median for those taxa retained for determination of the MFL in the right-hand column. Figure 7-1 compares the application of both a robust regression (Wessel 2009) and ordinary least squares (Greenwood 2008).

Table 7-1 Response of fish and invertebrate abundance to reduced flows

Taxa	Baseline Abundance		85% Abundance		Flow at 85% Abundance	Flow Reduction Evaluated	Flow Reduction Retained
	(#/channel)	(#/100 ²)	(#/channel)	(#/100 ²)	(cfs)	(%)	(%)
Plankton Net							
<i>Anchoa mitchilli juveniles</i>	229,888	----	195,405	----	62.3	1.0	1.0
<i>Hageria rapax</i>	458,012	----	389,310	----	61.8	1.9	1.9
Dipterans, chironomid larvae	434,562	----	369,378	----	61.6	2.3	2.3
Seine and Trawl							
<i>Farfantepenaeus duorarum (T)</i>	----	0.33	----	0.28	53.4	15.2	15.2
<i>Farfantepenaeus duorarum (S)</i>	----	0.96	----	0.82	52.2	17.2	17.2
<i>Fundulus grandis</i>	----	2.46	----	2.10	55.5	11.9	11.9
<i>Lucania parva</i>	----	41.20	----	35.03	56.0	11.1	11.1
<i>Lucania goodei (seasonal)</i>	----	19.92	----	16.93	62.4	0.9	--
<i>Poecilia latipinna</i>	----	0.28	----	0.24	54.6	13.3	13.3
<i>Lepomis punctatus (seasonal)</i>	----	3.34	----	2.84	62.0	1.6	--
<i>Lagodon rhomboides (seasonal)</i>	----	8.90	----	7.60	51.7	17.9	--
Baseline flow = 63 cfs for all starting calculations.					median =	11.1	11.5

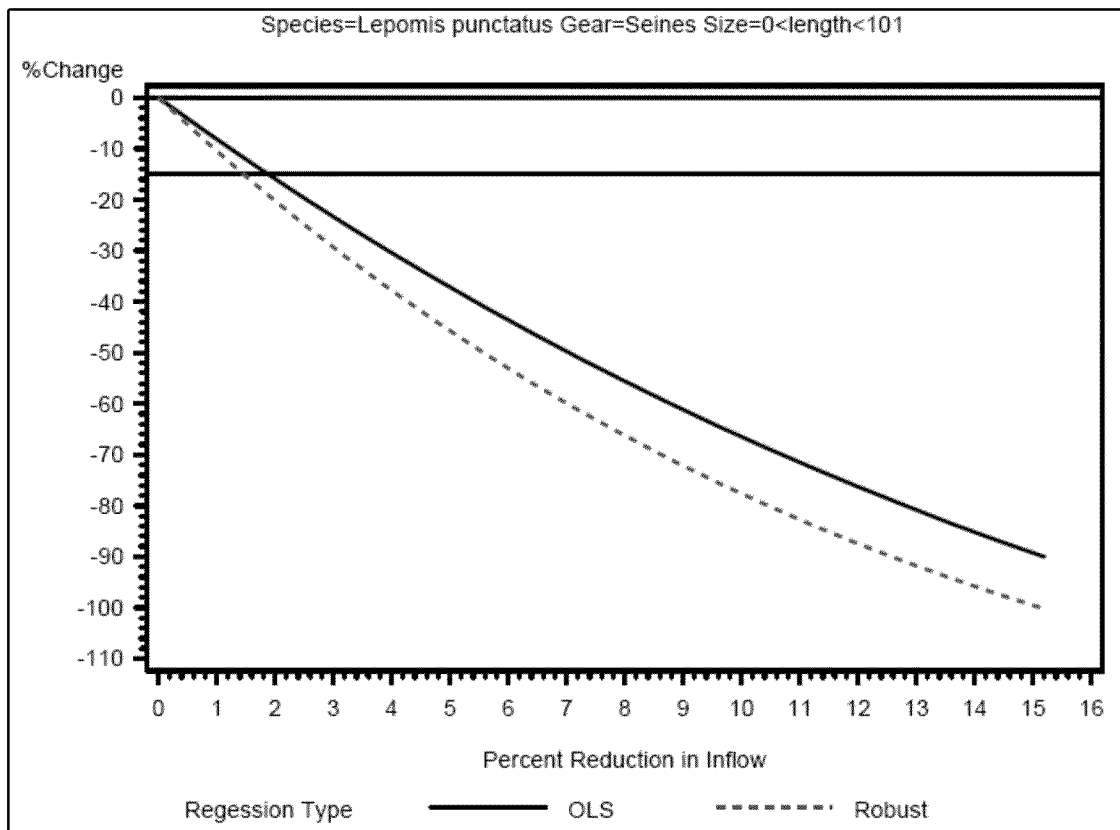


Figure 7-1 Predicted change in *Lepomis punctatus* abundance as a function of inflow reduction from the median flow (62.6 cfs) using OLS and robust methods.

7.2 Submerged Aquatic Vegetation Technical Approach

Aquatic vegetation sampling completed in 2005 for the District by Leverone (2006) was used to evaluate relationships between salinity and Braun-Blanquet density (Braun-Blanquet 1932) of the three most common native submersed aquatic species in the Chassahowitzka River. Given the strong relationship between salinity and flow in the river (see Section 4.2.3), these factors were examined with the intention of using statistical relationships between salinity and plant densities for evaluate potential effects associated with inflow reductions. For the analyses, Balanced Environmental Management Systems, Inc. developed fourth order polynomial regressions to approximate salinities associated with locations where maximum densities of *V. americana*, *N. guadalupensis* and *P. pectinatus* were observed in 2005

In practice, the density response to salinity was developed by forcing the regression curve past the maximum observed density point, resulting in the following 4th order polynomial form as an approximate estimation (See coefficient values in Table 7-2):

$$\text{Density} = a \cdot \text{Salinity}^4 + b \cdot \text{Salinity}^3 + c \cdot \text{Salinity}^2 + d \cdot \text{Salinity} + e$$

The fourth order polynomial models tended to predict unrealistically high density values for the three plant species at high salinities. Laboratory growth studies and field observations of the distribution of *V. americana* in the Caloosahatchee River estuary in south Florida indicate that this species is tolerant of salinities up to 10-15 ppt (Haller *et al.* 1974, Doering *et al.* 2002), although others report lower salinity tolerance values for the species (Haller *et al.* 1974, Ferguson and Wood 1994, sources cited in Doering *et al.* 2002). Ferguson and Wood (1994) report a salinity tolerance of 1-10 ppt for *N. guadalupensis*, although Haller *et al.* (1974) demonstrated toxicity when plants were exposed to 10 ppt in greenhouse growth experiments. Based on a review of available literature, Kantrud (1990) identified an optimal salinity range of 5-14 ppt for *P. pectinatus* and notes that the species distribution is often restricted or the plant is replaced by other species in areas where salinities range between 13 and 20 ppt.

Since the three taxa chosen have low to moderate tolerances to salinity, the observed density points upstream of the point of maximum recorded density were omitted for the non-critical situation in a favorable environment (greater freshwater). In addition, the fluctuation of the regression curve at high salinities would not impact the result of evaluation because the curve's steep descending portion from the peak-point would cover a very large range of flow reduction (more than 15 percent).

The peak density was then reduced by fifteen percent and the salinity associated with the reduced density (at 85 percent of the maximum) was back calculated. Using *Vallisneria americana* as an example, the maximum density is 3.8, which occurs when the salinity is at 3.08 ppt. Eighty-five percent of the peak density is 3.23, which occurs when the salinity is at 3.28 ppt (Table 7-3).

In the next step, salinities at the maximum and at the reduced densities are related to flow. The location of the salinity associated with maximum density was estimated for baseline flows (63 cfs) using the LSM regression introduced in Chapter 4.2.2. A flow of 63 cfs is expected to produce a salinity of 3.08 ppt at Rkm 6.15 in the Chassahowitzka River. Holding this location constant, but substituting the salinity at reduced density (3.28 ppt), the LSM equation is solved for flow at 85 percent maximum density. At a reduced flow of 62.30 cfs (1.12 percent reduction), the salinity at Rkm 6.15 would be 3.28 ppt. Thus, *Vallisneria americana* growing at this point would experience an increase in salinity from 3.08 to 3.28 ppt, resulting in an expected loss of density of fifteen percent.

Unfortunately, the curve is too restrictive to rely on the results. A 15 percent reduction in density would be predicted to occur at a salinity of just 0.2 ppt greater than the maximum. This response does not seem reasonable, as the documented salinity tolerance for *Vallisneria americana* is 0 to 9 ppt (Luczkovich, 2009, online citation).

The SAV model was not used in developing the Chassahowitzka River MFL because the response seemed unreasonable. The evaluation of flow requirements for dominant native SAV species was based on the relationship of flow and salinity patterns. Reductions in SAV density would be related to flow reductions by evaluating the reduction necessary to create the salinity regime that corresponds to the lower density.

Table 7-2 Coefficients of SAV density response to salinity (based on Leverone 2006 data)

Taxa	R ²	a	b	c	d	e
<i>Vallisneria americana</i>	0.96	0.0031	-0.1226	1.7616	-10.7940	23.64
<i>Najas guadalupensis</i>	0.83	0.0035	-0.1347	1.8490	-10.6930	22.31
<i>Potamogeton pectinatus</i>	0.81	0.0019	-0.0720	0.9578	-5.3309	10.88

Table 7-3 Response of dominant SAV density to reduced flow

Taxa	Max. Density (M.D.)	Relevant Salinity (ppt)	85% Max. Density	Relevant Salinity (ppt)	Baseline Flow (cfs)	Rkm max density	Flow at 85% M.D. (cfs)	Flow Reduction (%)
<i>Vallisneria americana</i>	3.8	3.08	3.23	3.28	63	3.5	62.30	1.12
<i>Najas guadalupensis</i>	3.3	3.08	2.81	3.27	63	7.0	62.33	1.06
<i>Potamogeton pectinatus</i>	2.9	2.28	2.47	2.51	63	7.0	62.19	1.29

7.3 Application of Salinity Habitat Model

The results of the salinity habitat model reported by Dynamic Solutions, LLC (2009) were used directly (Table 7-4). Dynamic Solutions, LLC conducted hydrodynamic model runs analyzing the following spring flow reductions:

- Base Case (no reduction),
- 10 percent Reduction,
- 20 percent Reduction, and
- 40 percent Reduction.

For each of these flow scenarios a three-year period was simulated, reflecting a “typical” period. The “typical” period was defined as a three-year period whose cumulative distribution function (CDF) of spring discharge is similar to the long-term record. The three-year period selected was 2004-2006 (Dynamic Solutions, LLC 2009). Details of the model may be found in Appendix 13

The model runs reduced flow rates for all the spring inflows by the corresponding fraction. Using the model results, the volumes, areas and shoreline lengths for each of the salinity ranges were computed. The change in volumes, areas and shoreline lengths between the baseline and the various flow reduction scenarios were then computed and compared to the 15 percent maximum habitat loss criteria (or 85 percent of the Baseline volumes/areas remaining).

Table 7-4 Flow reductions based on a 15% loss of volume, area or shoreline length for the salinity ranges.

Salinity Range (ppt)	Flow Reductions Based on Volumes (%)	Flow Reductions Based on Area (%)	Flow Reductions Based on Shoreline Length (%)
0 to 2	22	23	30
0 to 5	13	15	13
0 to 10	23	26	26
0 to 15	> 40	> 40	> 40
Values reported by Dynamic Solutions LLC. Impacts of Withdrawals on the Chassahowitzka River System. 2008.			

7.4 Manatee

Using the critical manatee habitat thermal criteria described in Section 6.1.5, the manatee refuge area was estimated from model results for a critically cold time period of January 4-6, 2002. During this period there were no areas inside of the Chassahowitzka River System that had manatee habitat meeting the chronic habitat criteria. Figure 7-2 shows typical plan view of water temperature during the “worst case” period. Sections of the river that are shaded in red meet the thermal criteria of $\geq 68^{\circ}\text{F}$ (20°C). Much of the upper river meets the temperature criteria. However, water depths, especially at low tide, are less than 3.8 feet (1.16m) (Figure 7-3). The middle to lower part of the system has sufficient depths but is too strongly influenced by the Gulf temperatures and remains too cold to serve as a refuge. Thus, a suitable overlap of both warm and deep water under baseline conditions does not appear to exist in the Chassahowitzka and thus a chronic thermal MFL could not be determined.

However, evaluation of the acute conditions indicated that an area of 27 acres and 5.65 million cubic feet provide suitable habitat. Flow reductions of 11 percent resulted in loss of 15 percent of the area and a flow reduction of 15 percent resulted in a 15 percent loss of volume.

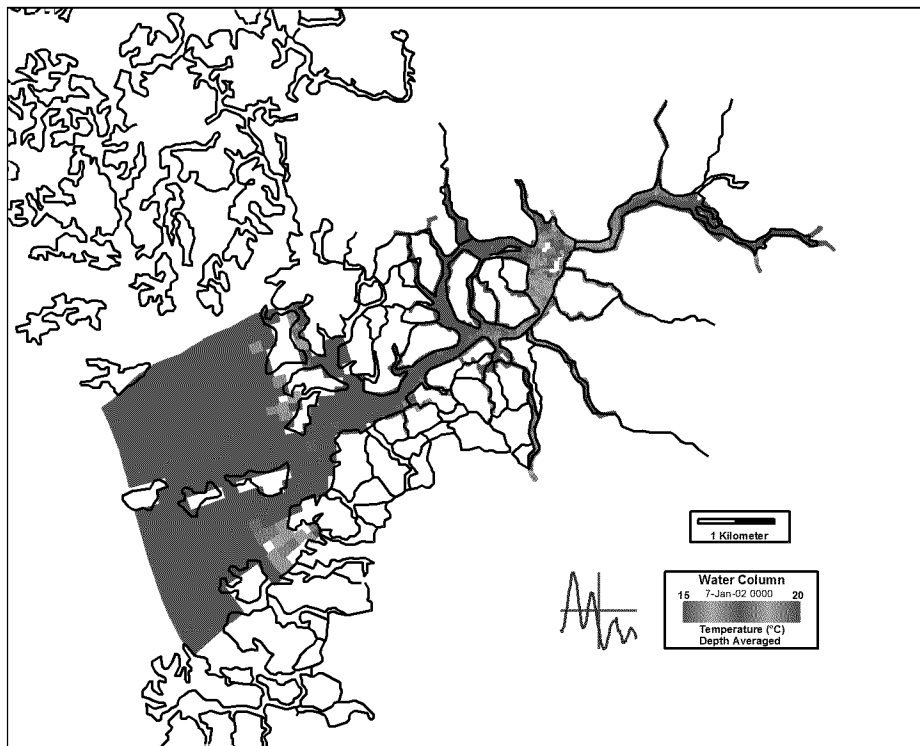


Figure 7-2 Plan view of water temperatures during the critically cold period

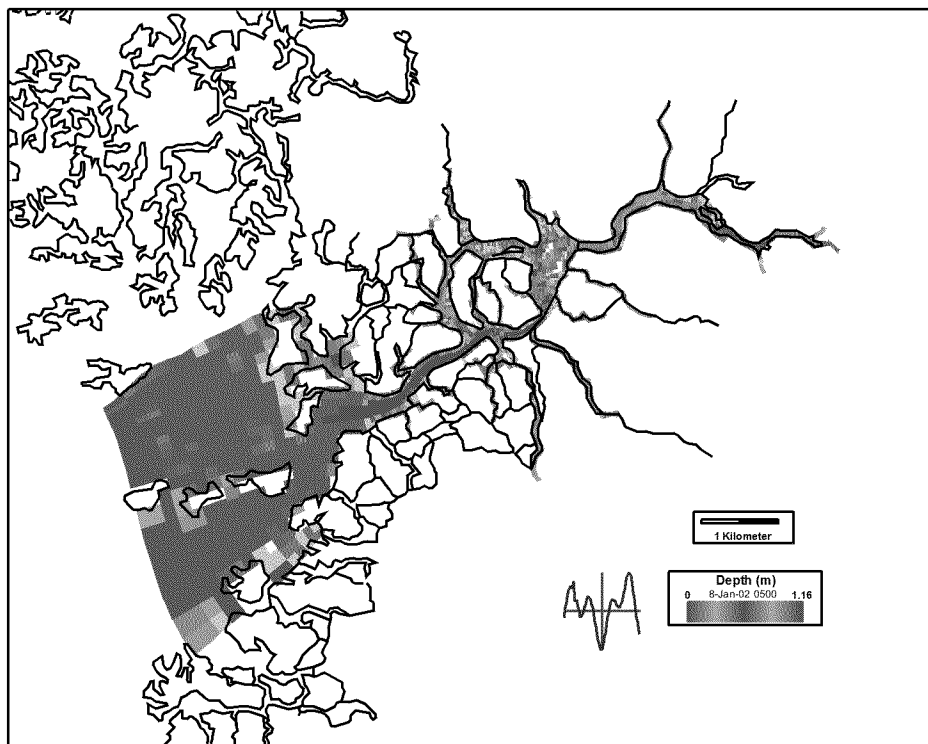


Figure 7-3 Plan view of water depths at low tide during the critically cold period.

CHAPTER 8 - CONCLUSIONS AND DISTRICT RECOMMENDATIONS FOR MFL

8.1 Summary of Outcomes

The tools described in Chapter 5 were applied to the criteria presented in Chapter 6. Examples were provided in Chapter 7. For each resource, an estimate of the percentage reduction of seasonal flow that would cause a presumed significant harm (e.g. 15 percent loss of resource or habitat) was determined. The resources evaluated and basis of flow evaluation include:

- ☐ Salinity Habitat
 - Area
 - Volume
 - Shoreline length
- ☐ Fish and Invertebrates
 - *Anchoa mitchilli* juveniles (bay anchovy)
 - *Hargeria rapax* (tanaid)
 - Dipterans, chironomid larvae (midges)
 - *Farfantepenaeus duorarum* (pink shrimp) (seine)
 - *Farfantepenaeus duorarum* (pink shrimp) (trawl)
 - *Poecilia latipinna* (sailfin molly)
 - *Lucania parva* (rainwater killifish)
- ☐ West Indian Manatee
 - Acute thermal habitat – area and volume

The results are summarized in Table 8-1. Not included in the table are the results for the SAV community because the confidence in the results was low. Also excluded were fish/invertebrate responses based on seasonal flow, benthic diversity and mollusc. The latter two responses were positively related to salinity (and thus inversely related to flow).

The reductions in flow that meet the threshold criteria established in Chapter 6 are presented in both tabular (Table 8-1) and graphic (Figure 8-1) form. The three most conservative reductions involved the plankton tow fish/invertebrate abundance (1.0, 1.9 and 2.3 percent flow reduction). It is unclear whether these hypersensitive results are an artifact of a spring system with nearly constant flow, or if these represent true ecological response to flow. However, for the fish and invertebrate resource it was determined that the median of determinations for species with significant responses should be used. The median of the seven determinations for reduction in baseline flow for the fish/invertebrate abundance is 11 percent flow reduction. This 11 percent flow reduction is also the most restrictive outcome and as such, this value was used to establish the MFL.

Table 8-1 Summary of Chassahowitzka MFL results (Highlighted results not included in MFL determination.)

Resource	Criteria	Reduction in Baseline Flow
Salinity Habitat		(%)
2 ppt - volume	15% loss in volume	22
5 ppt - volume	15% loss in volume	13
10 ppt - volume	15% loss in volume	23
15 ppt - volume	15% loss in volume	>40
2 ppt - area	15% loss in area	23
5 ppt - area	15% loss in area	15
10 ppt - area	15% loss in area	26
15 ppt - area	15% loss in area	>40
2 ppt - shoreline length	15% loss in length	30
5 ppt - shoreline length	15% loss in length	13
10 ppt - shoreline length	15% loss in length	26
15 ppt - shoreline length	15% loss in length	>40
Fish / Invertebrate Abundance		
<i>Anchoa mitchilli</i> juveniles (#/channel)	15% loss in abundance	1
<i>Hageria rapax</i> (#/channel)	15% loss in abundance	2
Dipterans, chironomid larvae (#/channel)	15% loss in abundance	2
<i>Farfantepenaeus duorarum</i> (#/100m ²)	15% loss in abundance	17
<i>Farfantepenaeus duorarum</i> (#/100m ²)	15% loss in abundance	15
<i>Fundulus grandis</i> (#/100m ²)	15% loss in abundance	12
<i>Lucania parva</i> (#/100m ²)	15% loss in abundance	11
<i>Lucania goodei</i> (#/100m ²) Seasonally derived	15% loss in abundance	1
<i>Poecilia latipinna</i> (#/100m ²)	15% loss in abundance	13
<i>Lepomis punctatus</i> (#/100m ²) Seasonally derived	15% loss in abundance	2
<i>Lagodon rhomboids</i> (#/100m ²) Seasonally derived	15% loss in abundance	18
Fish / Invertebrate Media		12
Benthos		
Diversity - Positive response with salinity - not included	15% loss of diversity	
SAVDensity		
<i>V. americana</i> (Not used - see text)	15% loss of peak density	1
<i>N. guadalupensis</i> (Not used - see text)	15% loss of peak density	1
<i>P. pectinatus</i> (Not used - see text)	15% loss of peak density	1
Mollusc		
<i>Crassostrea virginica</i> - Optimal salinity outside sample domain - not used.	15% loss of peak abundance	
West Indian Manatee		
Acute thermal refuge (volume)	15% loss in volume	15
Acute thermal refuge (area)	15% loss of area	11

MFL_results.xls

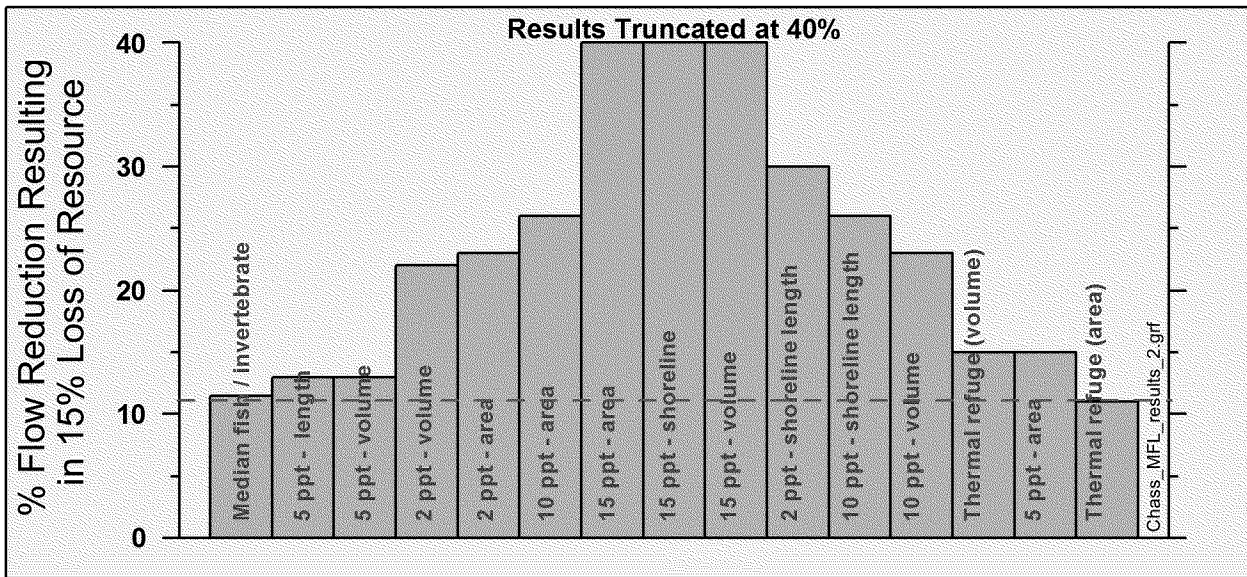


Figure 8-1 Summary of Chassahowitzka River MFL results.

8.2 Long-Term Expected Flows and Recommended Minimum Flows for the Chassahowitzka River System

In consideration of the results presented, it is recommended that the flow for the Chassahowitzka River system be maintained at 89 percent of the baseline flow. The assumed MFL for the associated creeks and springs, including Blind Springs, is also an eleven percent reduction in baseline flows. Long-term expected flows in the form of five and ten-year mean and median flows were developed to accommodate variations in climate. These minimum long-term flow statistics should be maintained in the presence of withdrawals.

In order to define a hydrologic reference and to accommodate variations in climate, the recommended MFL (11 percent reduction) was applied to the baseline flows and the average daily flow for each calendar year was calculated for the years 1967 through 2007. Next, a running five-year average was determined from these annual averages for the period of record and the minimum five-year period (e.g. 1993-1997) was identified. The process was repeated for a ten-year moving average. Finally, the procedure was repeated using the median daily flow for each calendar year from 1967 through 2007. The results are summarized in Table 8-2. These values are intended to serve as a hydrologic reference for climate conditions similar to those experienced during 1967 – 2007 baseline period.

Table 8-2 Long term expected minimum flows corresponding to recommended MFL

Criterion	Minimum Flow (cfs)
Minimum 10-Year Moving Average (based on annual average flows)	50.30
Minimum 10-Year Moving Average (based on annual median flows)	49.85
Minimum 5-Year Moving Average (based on annual average flows)	48.97
Minimum 5-Year Moving Average (based on annual median flows)	48.32

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CHAPTER 10 - APPENDICES – NUMBERED AND BOUND SEPARATELY

10.1 Heyl, M.G. Technical Memorandum- Estimation of Historical Chassahowitzka River Flows.

10.2 Basso, R. Technical Memorandum dated December 1, 2008 to Marty Kelly and Mike Heyl- Predicted Groundwater Withdrawal Impacts to Chassahowitzka Springs based on Numerical Model Results

10.3 Yobbi, Ungaged Flow. Letter Report

10.4 Leverone, J.R. 2006 Collection, Enumeration and Analysis of Invertebrate Community and Substrate in the Chassahowitzka River, Florida: Methodology and Data Report. Mote Marine Laboratory Technical Report No. 1085. Prepared for Southwest Florida Water Management District.

10.5 Janicki Environmental Inc, 2006. Analysis of Benthic Community Structure and Its Application to MFL Development in the Weeki Wachee and Chassahowitzka Rivers. Prepared for Southwest Florida Water Management District.

10.6 Clewell, A.F., M.S. Flannery, S.S. Janicki, R.D. Eisenwerth and R.T. Montgomery. 2002. An Analysis of Vegetation-Salinity Relationships in Seven Tidal Rivers of the Coast of West-Central Florida (Drafeet). A technical report of the Southwest Florida Water Management District. December, 2002.

10.7 Water Quality graphics- Spatial Trends and Response to Flow.

10.8 Grabe, S.A and A. Janicki. 2008. Analysis of Benthic Community Structure in Tributaries to the Chassahowitzka River. Prepared for Southwest Florida Water Management District. July 2008.

10.9 Janicki Environmental. 2007. Development of Analytical Tools for Quantifying Minimum Flows in Southwest Florida Tidal

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10.10 Greenwood, M.F.D, E.B. Peebles, S.E. Burghart, T.C. MacDonald, R.E. Matheson, Jr., and R.H. McMichael, Jr. 2008. Freshwater Inflow Effects on Fishes and Invertebrates in the Chassahowitzka River and Estuary. Prepared for Southwest Florida Water Management District by Florida Fish and Wildlife Conservation Commission and University of South Florida.

10.11 Estevez, E.D. 2007 Chassahowitzka River Mollusk Survey. A letter report prepared for Southwest Florida Water Management District by Mote Marine Laboratory. April 16, 2007.

10.12 Montagna, P. 2006. A Multivariariate Statistical Analysis of Relationships between Freshwater Inflows and Mollusk Distributions in Tidal Rivers in Southwest Florida. Prepared for Southwest Florida Water Management District. December 2006.

10.13 Dynamic Solutions, LLC. 2009. Impacts of Withdrawals on the Chassahowitzka River System. Prepared for Southwest Florida Water Management District.

CHAPTER 11 - REPORT REVIEWS AND DISTRICT RESPONSES

11.1 Peer Review Panel and Responses

SCIENTIFIC REVIEW OF THE CHASSAHOWITZKA RIVER SYSTEM RECOMMENDED MINIMUM FLOWS AND LEVELS

Scientific Peer Review Report

June 30, 2010

Prepared For:
Southwest Florida Water Management District
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***Scientific Peer Review of Proposed Minimum Flows and Levels for the
Chassahowitzka River System, Florida***

EXECUTIVE SUMMARY

These studies were conducted by the Southwest Florida Water Management District (the District) because Florida Statutes (§373.042) mandate the District's evaluation of minimum flows and levels (MFLs) for the purpose of protecting the water resources and the ecology of the Chassahowitzka River, Bay and Estuary System from "significant harm" that might result from continued reductions of freshwater inflows from the contributing watersheds in the future. With appropriate water management, including science-based MFL rules for environmentally safe operation of water supply projects from ground and surface water resources, the District can ensure that the Chassahowitzka ecosystem and its associated tidal (estuarine) marshes, brackish wetlands and artesian springs will continue to provide essential food and cover for the myriad of marine and estuarine-dependent fish and wildlife, as well as freshwater species in the headwaters, that need them for successful survival, growth and reproduction in these beautiful waters of interest.

The District is to be commended for voluntarily committing to independent scientific peer review of its MFLs determinations. The Scientific Review Panel (the Panel) finds that the District's goals, data, methods and conclusions, as developed and explained in the MFL report, are reasonable and appropriate. The District's multi-species approach is to be applauded because it does not ignore species with variable life history requirements. The District approached this analysis in an appropriately holistic manner; that is, with attention paid to both the ecological requirements of the river system and to the various watershed and springshed segments of the contributing landscape already modified by humans.

The Panel supports the District's finding that changes in the shallow-water distribution of estuarine-dependent fishes and shellfish is related to freshwater inflow and salinity regimes. Freshwater discharges attract these organisms, particularly the young-of-the-year, into areas that provide habitat (i.e., food and cover) in which they can survive and grow. In particular, the Panel notes that the entire Chassahowitzka River System appears to be tidal (read: estuarine) and the ecosystem contains many important nursery habitats for fish and wildlife, including intertidal marshes and spring run wetlands that deserve special consideration and protection. The Panel recognizes the Chassahowitzka springs, river, bay and estuary as parts of one ecosystem, which serves as a prime example of the classic artesian systems found on the Florida Springs Coast, where the mineral content in the spring water resembles minerals found in sea water, allowing an interesting mix of freshwater, estuarine and marine species.

Overall, it appears to the Panel that the MFL determination is adequate and based on the best available data, but the lack of detailed knowledge about the hydrogeology of the contributing springs, which seem to behave differently from each other and vary in water quality, would suggest that any MFL expressed in cfs alone may be somewhat inadequate or at least requires careful monitoring during implementation. Especially if groundwater withdrawals on the inland side of the aquifer, seawater intrusion into the artesian formation on the Gulf side, or other potential impacts (e.g., increased nitrogen and other pollutants) can affect the water quality of the Chassahowitzka ecosystem in the future, weakening the value and accuracy of the MFL as the District goes forward

with water management in this area. Until then, the Panel recommends that the District follow the Precautionary Principle and establish the initially recommended MFL as based on best available data and analyses until more and better scientific information is available in the future to better understand how changes in the springshed and the spring flows, both in quantity and quality, will affect the Chassahowitzka River System.

As the District moves forward to plan and supply water in the future to the people of the region, their economy and their environment, the Panel strongly recommends that the District continue to monitor the system for the purpose of verifying that the MFL is having its intended effect of maintaining the ecological health and productivity of this outstanding waterway. The verification monitoring might include spring flows, stream flows, tidal flows, basic water quality (e.g., temperature, salinity, pH, DO, chlorophyll, minerals and nutrients) and changes in vegetation, benthos, fish and shellfish, particularly during the spring season, which coincides with the beginning of peak utilization of nursery habitats by many estuarine-dependent fish and shellfish species in this part of Florida.

INTRODUCTION

The Southwest Florida Water Management District (the District) is mandated by Florida statutes to establish minimum flows and levels (MFLs) for state surface waters and aquifers within its boundaries for the purpose of protecting water resources and the ecology of the area from “significant harm” (Florida Statutes, 1972 as amended, Chapter 373, §373.042). The District implements the statute directives by periodically updating a list of priority water bodies for which MFLs are to be established and identifying which of these will undergo a voluntarily independent scientific review. Under the statutes, MFLs are defined as follows:

1. A minimum flow is the flow of a watercourse below which further water withdrawals will cause significant harm to the water resources or ecology of the area; and
2. A minimum level is the level of water in an aquifer or surface water body at which further water withdrawals will cause significant harm to the water resources of the area.

Revised in 1997, the Statutes also provide for the MFLs to be established using the “best available information,” for the MFLs “to reflect seasonal variations,” and for the District’s Board, at its discretion, to provide for “the protection of nonconsumptive uses.”

In addition, §373.0421 of the Florida Statutes states that the District’s Board “shall consider changes and structural alterations to watersheds, surface waters and aquifers, and the effects such changes or alterations have had, and the constraints such changes or alterations have placed on the hydrology of the affected watershed, surface water, or aquifer....” As a result, the District generally identifies a baseline condition that realistically considers the changes and structural alterations in the hydrologic system when determining MFLs. While flow-related alterations were considered minimal in this MFL Report, it is still important to understand because the Chassahowitzka River System has source waters that are dominated by artesian spring flows from the Floridan aquifer, and these are directly affected by groundwater pumping and pollution.

Current state water policy, as expressed by the State Water Resources Implementation Rule (Chapter 62-40.473, Florida Administrative Code) contains additional guidance for the establishment of MFLs, providing that "...consideration shall be given to the protection of water resources, natural seasonal fluctuations, in water flows or levels, and environmental values associated with coastal, estuarine, aquatic and wetlands ecology, including:

1. Recreation in and on the water;
2. Fish and wildlife habitats and the passage of fish;
3. Estuarine resources;
4. Transfer of detrital material;
5. Maintenance of freshwater storage and supply;
6. Aesthetic and scenic attributes;
7. Filtration and absorption of nutrients and other pollutants;
8. Sediment loads;
9. Water quality; and
10. Navigation."

The Panel notes that Chapter 373.042(2) of the Florida Statutes directs the state water management districts to adopt MFLs for "all first magnitude springs, and all second magnitude springs within state or federally owned lands purchased for conservation purposes." Presumably, this would include the Chassahowitzka River Swamp Sanctuary, the Chassahowitzka National Wildlife Refuge, and other parts of the 60,348 acres of land and water habitats that have been preserved. Therefore, in addition to establishing an MFL for the Chassahowitzka River System, the District may be required to specifically identify or otherwise estimate MFLs for Chassahowitzka Springs and the other major springs that contribute flow to the river system, depending on land ownership. At some future time, the District may consider revising this flow recommendation in such a way that MFLs are specified for each contributing major spring, as well as for the overall river, bay and estuary system.

After a site visit on March 16, 2010 to perform a reconnaissance survey of the Chassahowitzka River System, the Panel held an initial meeting, discussed the scope of work and subsequently prepared their independent scientific reviews of the District's April 2010 draft report and associated study documents (e.g., appendices). The peer reviews were compiled by the Panel Chair and edited by all Panel Members into the consensus report presented herein.

BACKGROUND

The quantity, quality and timing of freshwater input are characteristics that define an estuary. Freshwater inflows affect estuarine (tidal) areas at all levels; that is, with physical, chemical and biological effects that create a vast and complicated network of ecological relationships (Longley 1994). The effects of changes in inflows to estuaries are also described in Sklar and Browder (1998) and reviewed in Alber (2002). This scientific literature describes and illustrates how changing freshwater inflows can have a profound impact on estuarine conditions: circulation and salinity patterns, stratification and mixing, transit and residence times, the size and shape of the estuary. In the end, the distribution of dissolved and particulate materials, including nutrients and sediments, may all be altered in ways that negatively affect the ecological health and productivity of coastal bays and estuaries.

Consequently, inflow-related changes in estuarine conditions will affect living estuarine resources, both directly and indirectly. Many estuarine organisms are directly linked to salinity, which determines the distribution of plants, benthic organisms and fishery species (Drinkwater and Frank 1994, Ardisson and Bourget 1997). If the distributions become uncoupled from their food source or preferred habitat, estuarine biota may be restricted to areas that are no longer suitable habitat for their survival, growth and reproduction. Potential effects of human activities, particularly reductions in fresh ground and surface water resources, on the adult and larval stages of fish and invertebrates include impacts on migration patterns, spawning and nursery habitats, species diversity and distribution, and production of lower trophic level (food) organisms (Drinkwater and Frank 1994, Longley 1994). Changes in inflow will also affect the delivery of nutrients, organic matter and sediments, which in turn can indirectly affect estuarine productivity rates and trophic structure (Longley 1994).

There are a number of approaches for setting freshwater inflow requirements of an estuary. The District prefers to use a "percent-withdrawal" method that sets upstream limits on water diversions or losses as a proportion of river flow. This links daily withdrawals to daily inflows, thereby preserving natural streamflow variations to a large extent. In some cases, a low-flow threshold or limit is employed as well. This type of inflow-based policy is very much in keeping with the approach that is often advocated for river management, where flow is considered a master variable because it is correlated with so many other factors in the ecosystem (Poff et al. 1997; Richter et al. 1997). In most cases, the emphasis is on maintaining the natural flow regime while skimming off surplus flows along the way to meet water supply needs. Normally, regulations are designed to prevent impacts to freshwater and estuarine resources during sensitive low-inflow periods, and to allow water supplies to become gradually more available as inflow increases. The rationale for the District's MFL setting, along with some of the underlying biological studies that support the percent-of-flow approach, is detailed in Flannery et al. (2002).

REVIEW

Developing minimum flow rules requires several steps: (1) setting appropriate management goals; (2) identifying indicators to measure characteristics that can be mechanistically linked to the management goals; (3) reviewing existing data and collecting new data on the indicators; and (4) assembling conceptual, qualitative, and quantitative models to predict behavior of the indicators under varying flow regimes. The first two steps above represent the overall approach to setting the minimum flow rule.

The District's management goal for the Chassahowitzka River System is to maintain ecosystem integrity and, thereby, protect ecological health and productivity. As a result, the District's MFL was developed to limit potential changes in aquatic and wetland habitat availability associated with reductions in freshwater inflows that are dominated by spring flows (SWFWMD 2010). When biologically meaningful thresholds or breakpoints were not found in the more or less continuous physical, chemical and biological responses, as is often the case in field studies, a criterion of no more than a 15% loss of habitat or other resources, as compared to the estuary's baseline condition, was used as the limit for "significant harm." While the use of 15% as a constraint in the MFL analysis is a more or less arbitrary management decision, the Panel agrees that it is a reasonable approach for avoiding the most serious negative impacts, particularly where the

ecosystem has not been as well studied and has little historical data available on its essential parts. The remainder of this report is focused on review of data, methods and analyses used as a basis for the District's recommended MFL.

Specifically, the District's proposed MFL was determined based on the following information and procedures:

1. The Chassahowitzka River, located north of Tampa Bay on the Florida Springs Coast, has been designated as an "Outstanding Florida Water." River flows are dominated by artesian spring discharges from the upper Floridan Aquifer. The headwater springs alone are estimated to contribute 50% of the total river flows. The river system drains a surficial watershed of approximately 89 square miles (~56,960 acres); however, most of its stream flow comes from near coastal springs that have a 180 mi² (~115,200 acre) contributing area in their groundwater springshed. Although streamgaging did not occur before February 1997, the District estimated the overall median flow of the river at 63 cfs from 1967-2007 using a regression relationship with water levels in a nearby Floridan aquifer well at Weeki Wachee. All 5.6 miles (9 km) of the river are tidally influenced from the headwaters to Chassahowitzka Bay on the Gulf of Mexico (Figure 1).

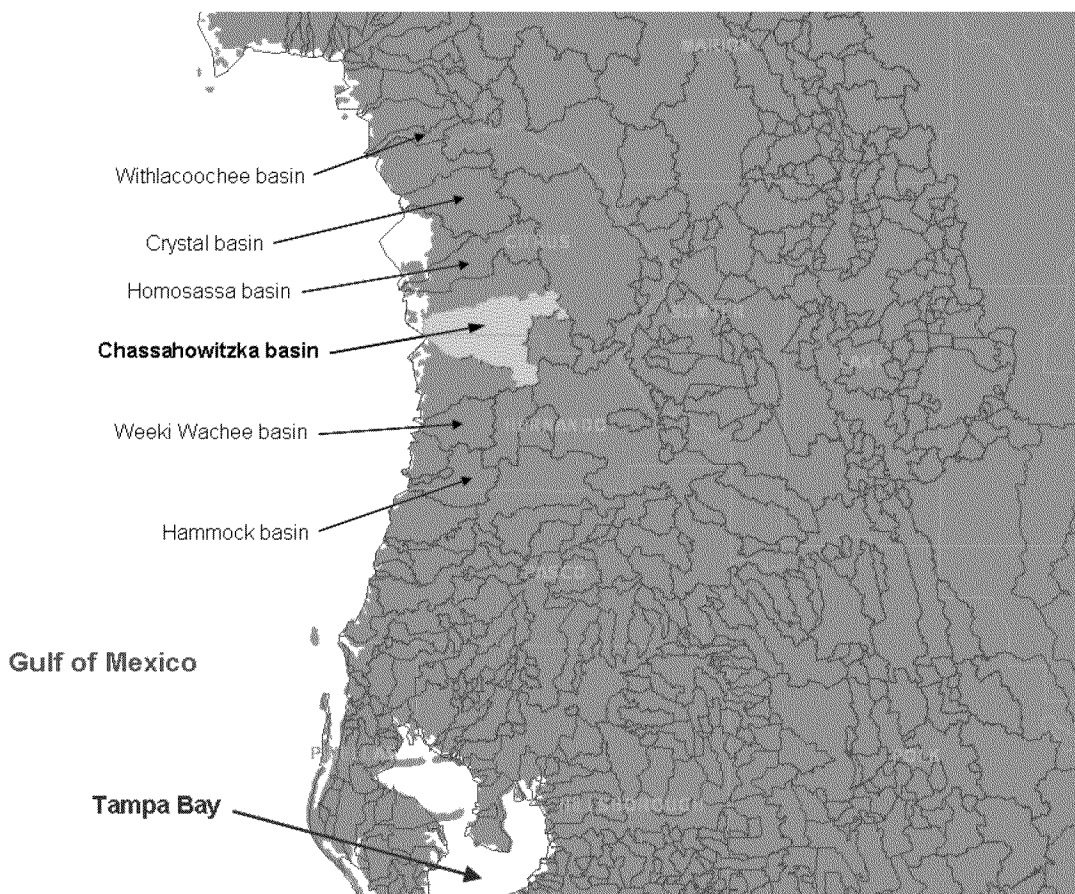


Figure 1. Location of the Chassahowitzka River Basin, Florida.

2. Ecological resources of concern identified by the District included submerged aquatic vegetation, benthic macroinvertebrates, mollusks, planktonic and nektonic fish and invertebrates, salinity-based habitat, and thermal refuge habitat for Manatees during critical cold periods. Numeric models and empirical regressions were used to assess their responses to reduced inflows (SWFWMD 2010).
3. The District evaluated 29 ecologically relevant responses. Since no inflection points or reasonable thresholds in the ecological responses were observed, the District used the previously mentioned 15% loss of habitat or resources as a default for the point of “significant harm.” The abundance of mollusks and the diversity of benthic macroinvertebrates were both positively related to salinity, which is inversely related to freshwater inflows and, thus, they were not used in the District’s minimum flow analysis. Also, a lack of confidence in the unusual responses from the SAV model (a 4th order polynomial salinity/SAV density equation) resulted in its omission from the MFL analysis as well. Similarly, the estimated hypersensitive responses (i.e., abundances predicted near zero with only 1-2 % flow reduction) of some planktonic fish and invertebrate taxa were considered suspect and were not used because the actual river flows had little variability (~11%) over the two-year sampling period (Greenwood et al. 2008). A couple of taxa in the seine and trawl sample analysis also had estimated hypersensitive seasonal responses that seemed unreasonable and were not used. The Panel believes that these were probably the result of the rather limited duration of the sampling program over a period with minimal changes in flow, which leaves little in the field of variation to be explained by the statistical routine.

As a result, the District decided to compute the median allowable flow reduction over all 10 of the fish and invertebrate taxa included in the response analysis and use that value (11%) in the MFL. Support for this MFL value comes from the Manatee thermal refuge analysis that indicates a 15% loss of thermal refuge area in the stream occurs at an 11% reduction in flows.

Long-term compliance standards in the form of five- and ten-year mean and median flows were then developed to accommodate variations in climate. The District’s intent is that these minimum long-term flow statistics should be maintained in the presence of future withdrawals in order to maintain 89% of the system’s baseline flow.

Hydrologic and Hydrodynamic Simulations

This part of the scientific review focuses on the District’s MFL report and the supporting numerical modeling discussed in the appendices (SWFWMD 2010). Appendix 10.2 discusses the application of the well known three-dimensional (3-D) groundwater model, MODFLOW (McDonald and Harbaugh 1988), supported by the U.S. Geological Survey and used here to assess the impact of groundwater withdrawals on spring flows in the river. Groundwater withdrawals within a 10-mile radius of the Chassahowitzka Springs were estimated at 14.4 mgd in 2005, mostly for non-consumptive uses associated with limestone mining (SWFWMD 2010, Appendix 10.2). Modeling 2005 groundwater withdrawals resulted in the conclusion that it caused only a 0.7 cfs reduction in the discharge of the main Chassahowitzka spring. This was considered insignificant; therefore, the impact of existing groundwater withdrawals was not used to correct or

otherwise adjust the estimated baseline flows from 1967-2007, nor was it considered in determining the MFL.

The Panel believes that the MODFLOW application is appropriate and the modeling effort seems well founded. Nevertheless, the detailed hydrogeology of the springs is not well known, unusual differences in flow quantity and quality are commonly exhibited by the contributing springs, and nitrate levels are increasing from pollution in both the watershed and the springshed.

The review of the 3-D hydrodynamic / salinity / temperature modeling effort discussed in Appendix 10.13 focused on addressing the following questions:

1. Was an appropriate numerical model employed?
2. Were the data employed adequate?
3. Was the development of the numerical grid employing available bathymetry data adequate?
4. Were boundary conditions appropriate?
5. Were the calibration / validation of the numerical model adequate?
6. Were the scenarios simulated by the model appropriate for determining an MFL?

Was an Appropriate Model Employed?

As stated in the main report and Appendix 10, the purpose for conducting the 3-D numerical hydrodynamic / salinity / temperature model study was to:

- ☐ Predict available thermal refuge habitat for Manatees during critically cold conditions.
- ☐ Predict the impact of various spring flow reductions on salinity zones in the estuary.

To address these issues, the District's consultant selected the Environmental Fluid Dynamics Computations (Hamrick 1992). EFDC is a well known general-purpose modeling package for simulating 3-D flow, transport, and some biogeochemical processes in surface water systems including coastal rivers, bays and estuaries. The model is supported by the EPA and used by several federal and state agencies. A discussion of the basic model's properties is provided in Appendix 10.2 and will not be repeated here. It should be noted that the version of EFDC applied here is one that interfaces with various pre- and post-processing routines developed by the District's consultant (Dynamic Solutions, LLC) that make the application of the model easier and allows for an improved processing of model output. The Panel finds that EFDC is an adequate hydrodynamic model code to apply to the Chassahowitzka River to address the issues of interest here.

Were the Data Employed Adequate?

In most numerical modeling studies, one always would like to have more data. Starting at the beginning, there must be sufficient data, especially bathymetry data on the water body's physical dimensions, to at least generate a computational grid, set numerical boundary conditions, and compare model results to data collected in the interior of the

numerical grid. An intensive bathymetry survey of the entire Chassahowitzka River System was supported by the District and conducted by the University of South Florida in 2007. These data along with bathymetry data for Chassahowitzka Bay obtained from NOAA resulted in the development of a good physical representation of the modeled length, area and volume of the system.

Water surface elevations, salinity, and temperature data were available at four USGS Stations (Nos. 02310674, 02310673, 02310663, and 02310650) beginning at the mouth of the Chassahowitzka River and extending up to the headwaters and the main springs at the upper end of the numerical grid. Data for the first station were collected from September 2006 – September 2007. Data for the next two stations were collected from October 2005 – September 2007. Water stage, salinity and temperature data were collected from May 2003 – September 2007 at the last station near the headwaters of the river. In addition, daily averaged flow data from the main spring were available for February 1997 – November 2007. Flow data and salinity data at five other springs that contribute to the Chassahowitzka River were very limited and based on just a few observations.

The Panel believes that there were sufficient data available to calibrate the model, although the calibration period involved a relatively low flow period. It is technically preferred that the calibration period cover a wider range of physical events in the system (e.g., a more complete range of flows, set ups and set downs of the ocean water surface, etc.). The more or less constant flow regime, dominated by the springs, led the modelers to be more comfortable with the shortened period.

Normally after calibrating a numerical model, it is applied to a separate set of data in what is called a “validation” phase of the model application. This was not done in the modeling study under review here. If the calibration period is long (e.g., a year or more), many modelers believe that both calibration and validation have been satisfied. Unfortunately, the calibration period in this study was only four months. The Panel questions whether calibration and validation have been accomplished with this rather short simulation period.

Water surface elevations, spring flow and temperature data were needed for the entire baseline period of 1967 – 2007 to determine worst case critical conditions for manatee habitat. A regression equation was developed using long term water surface levels from a USGS station located at Cedar Key, about 124 miles (200 km) from Chassahowitzka Bay. Historical data from 1997 - 2007 exist for spring flow only from the main spring. A regression equation relating the spring flow to water levels in a groundwater monitoring well nearby at Weeki Wachee was developed to generate flow estimates for the baseline period.

To generate a time series for temperature data at USGS Station No. 02310663, a regression equation was developed relating the water temperature to the air temperature at the St. Petersburg Airport. Each of these regressions had R^2 values above 0.75. As a result, the Panel agrees that the modeling study utilized all the data available, generated appropriate regressions to fill in missing data, and the data were adequate for conducting the modeling study, including the synthesized time series data used for determining critical three-day cold events for Manatee during the 1967-2007 baseline period.

Was the Numerical Grid Adequate?

The numerical grid over most of the river contained four cells across the river and four sigma layers in the water column profile. A sensitivity simulation using eight sigma layers was conducted. Doubling the number of vertical layers had more impact on the predicted salinity than the predicted temperature. Based on the beneficial salinity impact, perhaps eight layers should have been used. However, the report states that the time-step for stable computations was only 5 seconds. This means that computing time (i.e., CPU hours) might have become excessive with eight layers.

Since EFDC is a semi-implicit model, a basic question arises as to why the time-step had to be so small. The Panel understands that the controlling criterion on the time-step in this model is the water velocity through the computational grid cells. With horizontal grid cells being typically 164 feet by 282 feet, the Panel wonders why a much larger time-step could not have been used. In view of the reported effect of increasing the vertical layers in the aforementioned sensitivity analysis, the Panel would like to have seen the impact of doubling the number of horizontal cells across the river as well in order to evaluate any impacts on the simulation of shoreline salinity regimes under various flow reductions.

There is a lot of estuarine marsh area from the river mouth up to about river mile 3.1 (km 5) and the District's MFL report states that much of this marsh area is flooded during normal high tide levels, not just with storm tides. Because of this important inundation effect, the Panel believes that there should have been some discussion as to why the computational grid used in the modeling study did not incorporate the wetland marsh areas. This is especially puzzling since the EFDC model allows for wetting and drying of grid cells for just such a purpose.

Although the Panel believes that the questions above should be addressed, it also finds that the numerical grid is adequate to allow basic comparison of one model simulation of flows, salinities and temperatures with another in a precise, if not always the most accurate, manner.

Were the Boundary Conditions Adequate?

There were three separate modeling efforts. The **first** centered on calibrating the basic hydrodynamic, salinity, and temperature model. A four month period, November 2006 – February 2007, had overlapping periods where the data coverage was good for water levels (stage), salinity and temperature variations. In addition, data were available for the main spring discharge, salinity and temperature. The groundwater discharge and salinity for five other significant springs were based on very limited data and assumed to be constant. This seems to be a more or less reasonable assumption at first glance since conditions at the springs appear not to change much, at least over short periods of time (i.e., days to months). However, based on salinity measurements taken in the various springs during the Panel's March 16, 2010 field trip to the site, the Panel questions the salinity boundary conditions at the springs, which may not be always accurately represented in the model. Overall, the Panel finds that the boundary conditions were based on observed data and are, thereby, considered best available over this four month period.

Water surface elevations, salinity and temperature on the open bay portion of the grid were represented by USGS Station No. 02310674, which is located near the mouth of Chassahowitzka River. However, the salinity was “adjusted” by 4 ppt to better match observed salinities at the mouth of the river.

The **second** modeling effort centered on predicting manatee habitat for both chronic and acute criteria. These are given as follows:

- ☐ Chronic--Minimum depth of 3.8 ft with temperatures remaining above 68° F for the duration of critically cold three-day periods.
- ☐ Acute--Minimum depth of 3.8 ft with temperatures not be less than 59° F for four or more hours.

Using the long-term time series data developed for water level, flow and temperature discussed above, a joint probability analysis was conducted to determine critical condition periods with a return interval of 50 years. This analysis resulted in selecting the January 4-6, 2002 period for simulation. Water depths and temperatures on the open portion of the grid were obtained from the regression equations previously discussed. The salinity was taken from the four month calibration period. Measured discharge, salinity and temperature at the main spring were employed at the head of the numerical grid. Discharge, salinity and temperature were the same as from the calibration period for the other springs. Metrological data needed to compute surface heat exchange and equilibrium temperatures were taken from observations at the St. Petersburg Airport. The Panel finds that the assumptions made in setting the boundary conditions and the data employed are appropriate for this simulation effort.

The **third** modeling effort centered on assessing the impact of spring flow reductions on salinity. A three-year period (2004 – 2006) was selected for simulation. An analysis of the flow record for the 1967 – 2007 baseline period revealed that the cumulative distribution function (CDF) for flow during the three-year period was fairly typical of that for the longer baseline period. This would suggest that the simulation period was more or less representative of the baseline period. Again, measured data were employed where available and other data for setting boundary conditions were obtained from the regression equations. The Panel finds that the data utilized for setting boundary conditions and assessing the impact of flow reductions are appropriate and best available.

Were Calibration / Validation of the Model Adequate?

A four-month period (November 2006 – February 2007) was used for calibration of the hydrodynamic model. The calibration centered on comparing model results for water levels (stage), salinity and temperature at USGS Stations Nos. 02310674, 02310673 and 02310663. The calibration involved the visual inspection of graphical time series comparisons of observed and simulated measures, as well as statistical analyses. One statistic was the Nash-Sutcliffe efficiency coefficient. This statistic was developed to assess the goodness-of-fit of hydrology models, but it can be used for many other variables. The Panel believes that it is appropriate to employ this statistic, but recognizes that it has not been used often in other estuarine modeling efforts. The second statistic used was the Root Mean Square Error (RMSE). The Panel finds this statistic to be routinely employed in estuarine modeling and easy to understand.

Water Level Calibration

The calibration on water surface elevations (stage level) is very good, but in a relatively small system only 5.6 miles (9 km) long this is to be expected if the open boundary water tidal elevations are accurate. There is little dampening between USGS Stations 02310673 and 02310663, where the tidal ranges are about 3-4 feet at both locations. There is a Gulf tidal influence all the way to the main spring at Station No. 02310650, but the range of water level fluctuations there is only about 1 foot between normal ebb and flood tides. Unfortunately, results aren't presented for this station (Figure 2), which means that the Panel can not evaluate the model's ability to simulate the important observed tidal dampening between Station 02310663 and upstream Station 02310650.

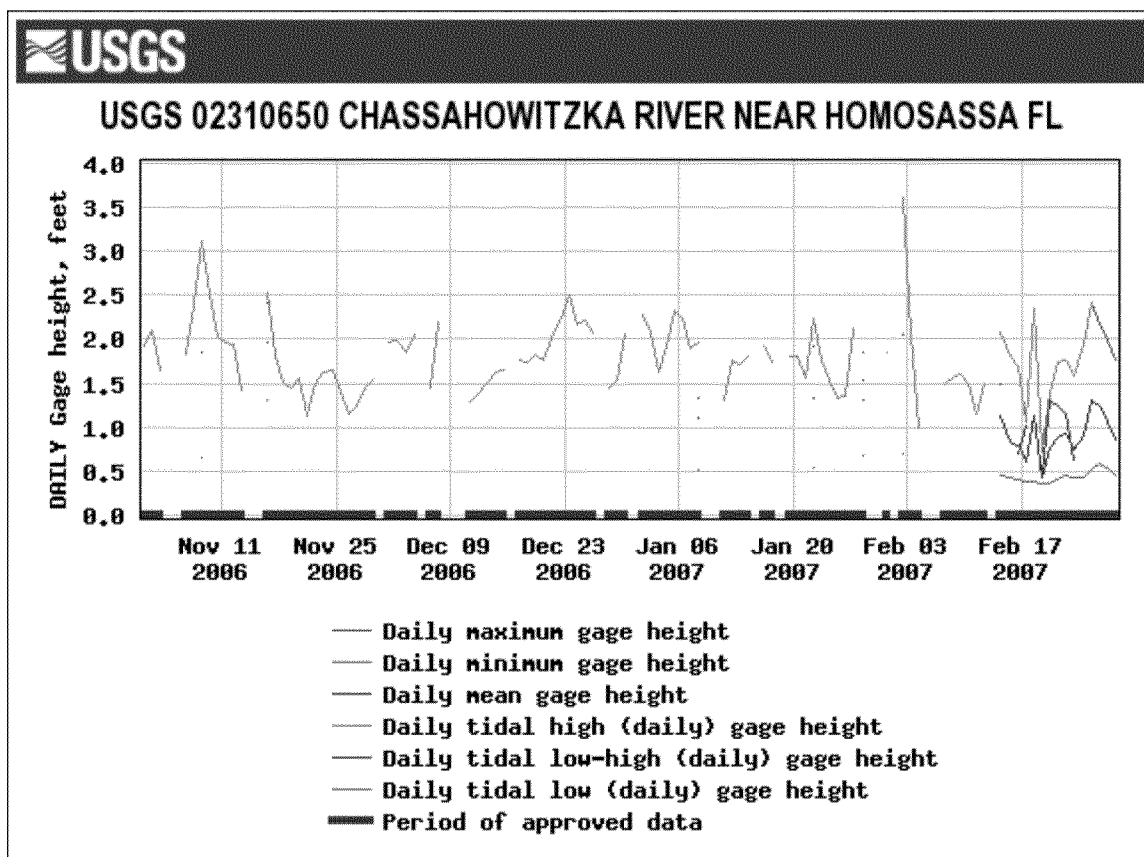


Figure 2. Daily Water Surface Elevations at USGS Station No. 02310650 during the November 2006 – February 2007 model calibration period.

Salinity Calibration

A time series comparison of salinity at Station 02310674 at the river mouth isn't given, although some statistics are presented. The statistics don't appear to be very good, which is somewhat surprising after the modelers made a special effort to "adjust" the open boundary salinity by 4 ppt in order to force a better match at the mouth of the river. The calibration at Stations 02310673 and 02310663 are better. An inspection of the time series plots shows that observed and computed salinities can differ by as much as 5 ppt, with the RMSE errors generally being around 2.0 – 2.5 ppt. The U.S.

Environmental Protection Agency (EPA 1990) recommends the Relative Mean Absolute Error (RMAE), a statistic defined as:

$$\text{RMAE} = \text{SUM} (\text{ABS} (O_i - C_i)) / \text{SUM} (O_i),$$

where O_i are observed values and C_i are computed values.

The EPA guideline for a calibrated salinity model is that the RMAE should be less than 20%. Since the model results are only being compared to other flow reduction simulation of the same model in the District's MFL analysis, rather than being used to make absolute predictions of the actual salinity levels, the Panel concludes that the salinity calibration is adequate for estimating relative differences due to reduced freshwater inflows. However, it should be noted that determining the level of uncertainty in a model, or a cascade of models, is a normal procedure in some scientific disciplines, but it is only just beginning to be applied to water resources projects. Therefore, the District should consider conducting quantitative uncertainty analyses on the models it uses for flow recommendations.

Temperature Calibration

A visual comparison of the temperature calibration shows that during flood stage there can be differences of 5 – 10 °F. However, the Nash-Sutcliffe statistic here is better (i.e., the values are closer to 1.0) than it was in the salinity calibration. The Panel understands that in large coastal bays, the water temperature is primarily driven by surface heat exchange; however, in smaller bodies of water such as the Chassahowitzka River estuary, the temperature of the artesian spring flow is also a major factor in determining water temperature in the river near the sources. The metrological data used to compute the surface heat exchange came from the St Petersburg Airport. If metrological data closer to the river had been available, the calibration might have been better. The Panel finds that the model does reproduce the cooling and warming trends very well and, thus, the temperature calibration is considered to be adequate.

Were the Simulated Scenarios Adequate for Determining a MFL?

The basic scenarios were simulated to predict available thermal Manatee habitat during critically cold spells, as well as the impact of various spring flow reductions on the length, area and volume of salinity habitats in the river. As previously discussed, time series data for water level (stage), temperature and spring discharge for the baseline period were generated from regression equations and were used in a joint probability analysis to determine critical condition periods for manatee habitat. The simulation of a critical period over January 4-6, 2002 revealed that there was no habitat satisfying the chronic criteria of at least 3.8 ft water depth at low tide with a water temperature greater than 68 °F. The major factor leading to the troubling finding was the controlling criterion for water depth. This result led the modelers to suggest, and the Panel agrees, that more refined bathymetry data should be collected to better define narrow channels in the upper river. Increasing the grid resolution with better bathymetry might yield some

available habitat after all. If the District supports additional modeling at some future time, the Panel recommends that this be done.

Salinity regimes in the river were simulated over the 2004-2006 three-year interval with spring flow reductions of 10%, 20% and 40%. Model results were then used to assess the impact of flow reductions on the length, area and volume of aquatic habitats in salinity zones of 0-2 ppt, 0-5 ppt, 0-10 ppt and 15 ppt. Cumulative Distribution functions were developed and areas under each of the curves for the different flow reductions were determined and compared to the no-flow reduction case. The analysis of salinity-based habitats (i.e., shoreline length, surficial area and water volume at 2, 5, 10 and 15 ppt) produced 12 estimates of habitat loss. The most sensitive were the length of shoreline habitat less than 5 ppt (15% loss at 13 % flow reduction), the volume of aquatic habitats less than 5 ppt (15% loss at 13% flow reduction), and the amount of habitat area less than 5 ppt (15% loss at 15% flow reduction).

This analysis led to the result that a 13% reduction in flow would result in a 15% loss of habitat for the low-salinity (0-5 ppt) zone. As a result, the Panel concludes that the application of the calibrated model to evaluate thermal and salinity habitats is appropriate and can be used to help determine a MFL for the Chassahowitzka River System.

Biota and Ecology of the Chassahowitzka River System

The District's effort to follow the legislative study mandate is focused on limiting flow reductions that could be significantly harmful to the natural resources of the area. The basic approach is to use a quantifiable reduction in habitat as the metric of choice, which is normally a good one. Since estuarine plants and animals live in a fluctuating salinity environment, they commonly have broad tolerances to changes in flows and mechanisms for dealing with physiological stress. Nevertheless, it is especially important at the fresh/brackish interface, where modest flow reductions can move the isohalines upstream, significantly reducing suitable freshwater habitat. As a result, the Panel agrees with the District that this would normally be the most relevant part of the spring-fed system to evaluate here. On the other hand, freshwater plants and animals are usually very intolerant of even low salinity conditions and are, thus, more likely to be impacted by lower freshwater inflows and increasing intrusion of brackish waters into previously fresh water habitat. In most riverine estuaries, seasonal low flow conditions are all that is required to eliminate intolerant freshwater species from the area of tidal influence.

The Panel understands and observed that the water of the Chassahowitzka River is mostly clear, slightly alkaline pH, extremely low in phosphorus concentrations, but high in nitrogen (SWFWMD 2010, Figure 4-4). The lack of phosphorus produces a general oligotrophic condition in the estuary where primary production, phytoplankton in particular, is also low. Although the nitrogen concentrations do not appear significantly related to the amount of spring flow, there is one troubling aspect to this nutrient, it exhibits a strong significant increase ($p = 0.0005$) with time (SWFWMD 2010, Figure 4-6).

Since it is primarily spring-fed, the Chassahowitzka River System has little seasonal variation. The Panel agrees that measuring the extent of and changes to the sensitive freshwater zone from reductions in flow is a logical approach to the MFL determination,

although it would be more comforting if the contributing springs could all be considered “fresh.” There were several important data sets in the study that suggest the analytical results utilized by the District for setting the MFL for the Chassahowitzka River System are still problematic at low flows because of the potential for saline discharges from the springs.

The District’s approach to the MFL can be interpreted as assuming that the major contributing springs and the headwaters of the river feeding the estuary are essentially fresh; however, Figure 4.1 (SWFWMD 2010) reveals that the entire system from headwaters to mouth has substantial salinity levels and qualifies as estuarine, not fresh waters. The biological significance here is related to the fact that even marine animals intolerant of freshwater can survive under near fresh (< 5 ppt) conditions if the important marine dissolved solids are sufficiently abundant to allow osmoregulatory substitution of critical ions. This expands their metabolic scope for activity and, thereby, their potential range of distribution in the ecosystem.

The floral and faunal communities present at the time of the Panel’s site visit and reconnaissance survey suggested that dissolved ions must be abundant in all of the springs, and this was confirmed by the District’s MFL Report and Appendices (SWFWMD 2010). For example, the Panel observed marine fishes, including the Mangrove snapper (*Lutjanus griseus*), all the way up to the headwaters and even in the main spring area, because salinity was still a couple parts per thousand salt above freshwater. Marine mammals, including Manatee (*Trichechus manatus latirostris*) and Bottle-nose dolphin (*Tursiops truncatus*), were also present in the immediate area that day. At Crab Spring, the water at the surface was notably saline. Here and in at least one other spring, the Panel observed a brown floc that has been described variously as brown diatom clusters or as iron-based precipitates, with visible deposits on the bottom. The latter would again suggest that the spring water contained high concentrations of dissolved solids. Data from the District showed iron (Fe) concentrations as high as 80 µg/L in Crab Spring.

The District’s MFL Report also provides faunal evidence that the headwaters were not populated by insect larvae and peracarid crustaceans considered typical of fully freshwater regions of other Florida estuaries. For example, the burrowing anthurid isopod, *Cyathura polita*, is considered a mesohaline species (Burbanck 1967), but in the Chassahowitzka River System it was a constituent of the plankton and benthic community virtually everywhere, including the headwaters. Again, this suggests that the fauna did not recognize the upper reaches of the Chassahowitzka River as a freshwater ecosystem. The District’s report notes that there is currently no freshwater/saltwater boundary in the river system. Perhaps this is why several of the biotic analyses produced ambiguous results or, like the benthos, respond to salinity in a positive way such that flow reductions increase salinity and their biotic diversity in this estuary.

It is not clear to the Panel that there is enough data on the discharge rates and water quality from the contributing springs prior to 1997 to be able to fully understand the pre-pumping state of the Chassahowitzka groundwater system. It is clear that the District can evaluate prior hydraulic pressure that drives the springs, but without more detailed hydrogeology of the artesian system, it is questionable if historical spring conditions can be adequately evaluated beyond some estimate of flow volume.

The various artesian springs that constitute the primary flow of the river have a wide range of discharges and salinities suggesting that they intersect different portions, or perhaps different depths, of the aquifer formation. For example, an analysis of solutes in water samples collected from Crab Spring suggests that the solutes are derived from ocean water. The oceanic ratio of Na to Mg is 8.213 (Sverdrup et al. 1942), while the ratio in the spring was reported at 7.680 (October 11, 1993), 8.322 (July 21, 1994) and 8.260 (October 25, 1994). The Panel's calculation of other ion ratios produces similar results, providing another piece of evidence that the dissolved solids in these springs were from oceanic sources (e.g., Gulf saline intrusion) rather than dissolved from the internal geology (read: rock strata) of the groundwater aquifer formation.

Scott et al. (2004) provide an additional analysis of the Chassahowitzka springs that argues that the saline water in these springs is derived from a past sea level high, which inundated the karst landscape and flooded the underlying aquifer with sea water. If this is correct, then the ocean-derived salts discharging from these springs today are fossil water contributions. There is a boundary layer in the aquifer above which freshwater sits and below which more saline water can be found. This means that future withdrawals of freshwater from the top can increase the amount of saline water in the aquifer, resulting in more saline discharges at the springs.

The Panel notes that reported chloride levels in the springs vary by an order of magnitude (SWFWMD 2010, Table 2.5) suggesting that the ultimate origin of their water could be from very different parts of the Floridan Aquifer. This concerns the Panel if modest changes in future aquifer pumping rates can potentially alter the amount and proportion of salts discharged from these springs. Unfortunately, the District's simple regression equation of river flow and water levels may be too inaccurate during low flow periods to adequately address the potential contribution of saline waters in spring discharges to the river. This means that the springflow MFL may have to be adjusted in the future as the District goes forward with its regional water management duties and responsibilities.

The Panel additionally finds that Chassahowitzka Springs data from the past half century strongly suggest that there has been a substantial change in the concentration of salt ions (e.g., Na and Cl), although the Cl/Na ratio appears to be ocean derived and varies little from the 1.8 ocean ratio (Sverdrup et al. 1942). Specifically, the concentration of chloride was 53 mg/L in 1941, 320 mg/L in 1971 and 680 mg/L in 2001 (Scott et al. 2004). Changes in levels of ocean-derived salts can be attributed to ground water withdrawals affecting the pathway of water discharged from the aquifer, or to severe and prolonged drought.

In the end, the Panel believes that a better understanding of the hydrogeology of these springs and an investigation of how groundwater withdrawals can affect the concentration of salts in these springs, as well as a better accounting of their individual contributions to the overall flow, will be required to fully address the MFL issues here.

Saltwater intrusion is a problem that has crept up on coastal water managers in many parts of the nation, and Florida is no exception, even if it's not the main problem at Chassahowitzka Springs right now. Continued development in the springshed can increase demand for freshwater water and the resulting strain on groundwater supplies can open the gates for more saltwater intrusion. According to the District, deposits of remnant sea water were left over from a time when much of the Florida Peninsula was

submerged thousands of years ago. When the oceans receded, not all the sea water was flushed out of the surficial aquifer systems. The Panel observes that this source of contamination, also known as "connate sea water," is the least common and least studied form of saltwater intrusion. While that may explain the past situation, it may not adequately predict the future of the Chassahowitzka River System.

Other Panel Comments

The District is to be commended for the thorough response to the questions and data requests from the Panel Members after their initial reading of the District's draft report.

Overall, it appears to the Panel that the MFL determination is adequate and based on the best available data, but the lack of detailed knowledge about the hydrogeology of the contributing springs, which seem to behave differently from each other and vary in water quality, would suggest that any MFL expressed in cfs alone may be somewhat inadequate or at least requires careful monitoring during implementation. Especially if groundwater withdrawals on the inland side of the aquifer, seawater intrusion into the artesian formation on the Gulf side, or other potential impacts of nutrients and pollutants can affect the water quality of the Chassahowitzka ecosystem in the future, weakening the value and accuracy of this initial MFL recommendation.

Therefore, the Panel recommends that the District follow the Precautionary Principle and establish the initially recommended MFL, which is based on the best available data and analyses, until more and better scientific information is available in the future to better understand how changes in the springshed and spring flows, both quantity and quality, will affect the Chassahowitzka River System.

As the District moves forward to plan and supply water in the future to the people, their economy and their environment, the Panel strongly recommends that the District continue to monitor the system for the purpose of verifying that the MFL is having its intended effect of maintaining the ecological health and productivity of the Chassahowitzka River System, including the associated bay and estuary. The verification monitoring might include spring flows, stream flows, tidal flows, basic water quality (e.g., temperature, salinity, pH, DO, chlorophyll, minerals and nutrients), and changes in wetland vegetation, benthos, fish and shellfish, particularly during the dry season, which coincides with the beginning of peak utilization of nursery habitats by estuarine-dependent fish and shellfish species in Florida.

ERRATA and EDITORIAL COMMENTS

Page	Paragraph	Line	Comment
9	3	3	Insert comma after Chapter 3.
9	4	3	Insert comma after Chapter 6.
10	Footnote		Elevate footnote 2 into superscript font ² .
11	Footnote		Elevate footnote 3 into superscript font ³ .
12	Last	2	Put parentheses around "See Figure 2-5 in section 2.3.1"
13	1	1	Change "sewer. ⁴ " to "sewer ⁴ ."
13	Footnote		Elevate footnote 4 into superscript font ⁴ .
14	1	3	Insert comma after "(1892-2006)."
20	1	4	Insert space after "Figure 2.6"
20	Last	1	Remove space between "(" and "Figure 2.6)."
20	Last	3	Insert comma after "mid-1960's"
31	1	8	Insert "Inc." after "Janicki Environmental"
37	3	17	Insert comma after "However" and put period at end of "Williams et al."
40	3	4	Insert comma after "Thus"
46	3		Put period at end of last sentence.
54	7	4	The Goldspotted killifish is <i>Floridichthys carpio</i> , not <i>Cyprinodon variegatus</i> , which is the Sheepshead minnow, a common species of pupfish. It is noted that the endemic Eustis Pupfish (<i>Cyprinodon variegatus hubbsi</i>) is present in the nearby Oklawaha River, Florida (Jordan 1993). Also, <i>C. variegatus</i> is <u>not</u> very sensitive to low D.O. and tolerates hypoxic (< 2 mg/L) waters rather well, while <i>F. carpio</i> exhibits extreme osmotic stress at moderate 4-5 mg/L D.O. concentrations (Kraill 1967).
55	Last	2	Insert comma after "transformation"
59	2	7	Insert comma after "determination"
63	Last	2	Insert comma after "composition"
64	Last		Change last word from "sytem" to "system"
66	Footnote		Elevate footnote 7 into superscript font ⁷ .
67	Footnote		Elevate footnote 8 into superscript font ⁸ .

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11.1.1 Response to Peer Review Panel Provided to Governing Board (Submitted to Governing Board 8/24/2010)

Resource Management Committee
August 24, 2010

Submit & File Report

Report from the Scientific Peer Review for Chassahowitzka River System and Staff Response (B209)

Purpose

To present the report documenting the findings of the voluntary independent scientific peer review of the *Chassahowitzka River Recommended Flows and Levels – April 2010 Draft*. Staff will be returning at a future date with proposed rule language and a request to initiate rulemaking.

Background/History

Staff completed a draft report recommending minimum flows for the Chassahowitzka River system that was submitted to the Governing Board at its April 27, 2010 meeting. The recommended Minimum Flow and Level (MFL) is to limit reductions in Chassahowitzka River flow to 11 percent of the baseline flow (i.e., unaffected by

withdrawals). The basis of the recommended MFL is contained in the report *Chassahowitzka River System Recommended Minimum Flows and Levels*. This report was submitted to an independent scientific peer review panel (Panel) for voluntary review. The Panel was composed of three scientists who have extensive experience in hydrology, ecology and freshwater inflow relationships. On March 16, 2010, staff accompanied the Panel on a field trip covering the 5.6 miles downstream from the main spring to the Gulf of Mexico. Several of the minor contributing spring runs (Crab Creek, Ryles Creek) were also traversed to their respective headsprings.

The Chassahowitzka River System is located on the west coast of Florida in Hernando and Citrus counties approximately 17 miles northwest of Brooksville. The headwater for the Chassahowitzka River is the Chassahowitzka Main Spring, but more than a dozen springs discharge additional Floridan aquifer flow into the Chassahowitzka River. The river receives a small amount of surface runoff from its 89 square mile watershed, but the overwhelming majority of flow arises from the 180 square mile springshed that produces a relatively constant discharge with little seasonal variation. It is designated an "Outstanding Florida Water" and the lower half of the river is part of the approximately 31,000-acre Chassahowitzka National Wildlife Refuge. For purposes of establishing MFLs, the main river, all named and unnamed springs and contributing tributaries and Blind Spring are considered part of the river system.

The main river is tidally influenced to the Main Spring. There is minimal development below the main spring but above the Main Spring, canals have been constructed and there is a small enclave of residences. Estimated discharge from the Main Spring has averaged 63 cubic feet per second (cfs) for the period 1967-2007.

Purpose/Approach

The District received the report of the Panel (Exhibit "A" attached) on June 30, 2010. The report was supportive of the District's conclusions, but recommended additional monitoring to advance the understanding of the reaction of the various smaller springs to increased groundwater withdrawals. In summary, the Panel concluded "*The Scientific Review Panel (Panel) finds that the District's goals, data, methods and conclusions, as developed and explained in the report, are reasonable and appropriate. The District's multi-species approach is to be applauded because it does not ignore species with variable life history requirements. The District approached this analysis in an appropriately holistic manner; that is, with attention paid to both the ecological requirements of the river system and to the various watershed and springshed segments of the contributing landscape already modified by humans.*"

Overall, the Panel made only a few specific recommendations and most were related to the future application of the hydrodynamic model. The Panel suggested that the District incorporate a quantitative uncertainty analysis, and the acquisition of additional bathymetric measurements to better define the narrow channels in the upper river so that the area modeled can be expanded to include the wetland marsh areas. Staff agrees with these suggestions. The District is committed to periodic re-evaluation of its MFLs and these recommendations will be incorporated into the re-evaluation.

The report goes on to state, "*Overall, it appears to the Panel that the MFL is adequate and based on the best available data, but the lack of detailed knowledge about the hydrogeology of the contributing springs, which seem to behave differently from each*

other and vary in water quality, would suggest that any MFL expressed as cfs alone may be somewhat inadequate or at least requires careful monitoring during implementation. . . . Until then, the Panel recommends that the District follow the Precautionary Principle and establish the initially recommended MFL as based on best available data and analysis until more and better scientific information is available in the future to better understand how changes in the springshed and the spring flows, both in quantity and quality, will affect the Chassahowitzka River System."

Staff agrees with the Panel's recommendation. The District is committed to better understanding the karst nature of all the springs and currently supports field-mapping efforts of the major spring systems. In addition, the District continues to monitor the water quality of both major and minor springs through the Water Quality Monitoring Program. The District is collecting water quality data eight of the springs in the Chassahowitzka River system and this data will provide the basis for the type of review suggested by the Panel.

Staff will return to the Board in the near future with proposed rule language necessary to establish the minimum flow for the Chassahowitzka River system.

Staff Recommendation: See Exhibit

This item is provided for the Committee's information only; no action is required.

Presenter: Mike Heyl, Chief Environmental Scientist
Resource Projects Department

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cc: Ecologic Evaluation Project File
PRJ File

11.1.2 Additional Comments Regarding Peer Review Report

[In addition to the Panel's primary recommendation that a better understanding of spring flow and water quality needs to be developed, the Panel did make several other comments that warrant discussion. Excerpts from the Panel's report are in black text and District comments are in blue italic.]

Page 15. Paragraph 2. ". . . With horizontal grid cells being typically 164 feet by 282 feet, the Panel wonders why a much larger time-step could not have used. In view of the reported effect of increasing the vertical layers in the aforementioned sensitivity analysis, the Panel would like to have seen the impact of doubling the number of horizontal cells across the river as well in order to evaluate any impacts on the simulation of shoreline salinity regimes under various flow reductions." *The Chassahowitzka EFDC model used a curvilinear grid structure. To cover the complexity of the stream network, along with the typical grid size, there is also a fine grid part of the domain. EFDC uses a Finite Difference explicit scheme that is subject to the Courant-Freidrich-*

Lewy (CFL) time step limits. It varies from 1.5 to 30 seconds. To achieve stability during the full computational period, a 5 second time step was used.

The number of cells was determined during the model development phase to optimize resolution while balancing runtimes. Doubling or changing the horizontal model grid resolution represents additional effort that was not deemed necessary for the sensitivity analysis. Based on experience and objectives of the study, the resolution of the horizontal grid was deemed sufficiently refined to represent the system.

Page 15. Paragraph 3 -4. "There is a lot of estuarine marsh area from the river mouth up to about river mile 3.1 (km 5) and the District's MFL report states that much of this marsh area is flooded during normal high tide levels, not just storm tides. Because of this important inundation effect, the Panel believes that there should have been some discussion as to why the computational grid used in the modeling study did not incorporate the wetland marsh areas. This is especially puzzling since the EFDC model allows for wetting and drying of grid cells for just such a purpose."

"Although the Panel believes that the questions above should be addressed, it also finds that the numerical grid is adequate to allow basic comparison of one model simulation of flows, salinities and temperatures with another in a precise, if not always the most accurate, manner."

The District agrees that the model would be improved by incorporating the marsh areas, but the basic limitation is that there is no bathymetry to support development of model grids over these areas and they are inaccessible except by airboat. Indeed the very existence of the marsh has complicated development of flow discharge measurements downstream of the marsh demarcation.

Page 19. Paragraph 2. ". . . , the Panel concludes that the salinity calibration is adequate for estimating relative differences due to reduced freshwater inflows. However, it should be noted that determining the level of uncertainty in a model, or a cascade of models, is a normal procedure in some scientific disciplines, but it is only just beginning to be applied to water resource projects. Therefore, the District should consider conducting quantitative uncertainty analyses on the models it uses for flow recommendations."

The District concurs with this suggestion and will include an evaluation of uncertainty in future model development and during re-evaluation of the current MFLs.

Page 22. Paragraph 4. "The District's approach to the MFL can be interpreted as assuming that the major contributing springs and the headwaters of the river feeding the estuary are essentially fresh; however Figure 4-1 (SWFWMD 2010) reveals that the entire system from headwaters to mouth has substantial salinity levels and qualifies as estuarine, not fresh waters."

The hydrodynamic model developed for the salinity evaluation did not assume freshwater discharge from the major springs. The observed salinity time series from location USGS 02310650 (Chassahowitzka nr Homosassa) was used as a boundary condition in the main river. The data for other sources is limited in

terms of rate of flow and salinity, but the following assumptions were incorporated into the EFDC model.

Spring	Discharge (cfs)	Salinity (ppt)
<i>Crab Creek</i>	<i>48.7</i>	<i>3.2</i>
<i>Potter Creek</i>	<i>18.6</i>	<i>5.5</i>
<i>Baird</i>	<i>5.7</i>	<i>6.5</i>
<i>Beteejay Head Spring</i>	<i>6.4</i>	<i><1</i>
<i>Blue Run</i>	<i>6.6</i>	<i>4.3</i>

11.2 Review Comments from Florida Fish and Wildlife Conservation Commission and District Response.

(Reproduced from Florida Fish and Wildlife Conservation Commission (FWC) correspondence to Mr. Marty Kelly dated June 7, 2010. FWC text in black. District responses are in italic blue text)

June 7, 2010

Mr. Marty Kelly
Ecologic Evaluation
Southwest Florida Water Management District
7601 U.S. Highway 301
Tampa, FL 33637-6759

RE: Chassahowitzka River Recommended Minimum Flows and Levels, April 2010
Draft, Southwest Florida Water Management District

Dear Mr. Kelly:

The Division of Habitat and Species Conservation, Habitat Conservation Scientific Services Section, of the Florida Fish and Wildlife Conservation Commission (FWC) has coordinated our agency's review of the Southwest Florida Water Management District's (SWFWMD) Chassahowitzka River Recommended Minimum Flows and Levels (MFL) draft report and provides the following comments and recommendations.

Project Description

The following has been taken directly from the draft report:

SWFWMD MFL Executive Summary

The headwaters for the Chassahowitzka River are formed by the Chassahowitzka Main Spring. More than a dozen springs discharge additional flow into the Chassahowitzka River from the Floridan aquifer. For the purpose of minimum flows development and implementation, the Chassahowitzka River and associated springs are collectively considered to be the Chassahowitzka River system. The river receives a small amount of surface runoff from its 89 square miles watershed, but the overwhelming majority of flow arises from the 180 square miles springshed which produces a discharge that varies little with season. The river flows 5.6 miles (9 km) from the headspring to the Gulf of Mexico at Chassahowitzka Bay. It is designated an "Outstanding Florida Water" and the lower half of the river is part of the more than 31,000-acre Chassahowitzka National Wildlife Refuge.

Salinity in the Chassahowitzka River system may vary from fresh to brackish at the headwater and increases substantially as water moves through the marsh and into the estuary, mixing with more saline Gulf of Mexico water. The river transitions from salt

marsh at the river's mouth to freshwater forested wetland approximately 3.1 miles (5 km) upstream from the river mouth.

Spring discharge is the primary freshwater source into the Chassahowitzka River system. However, continuous records are only available for the Chassahowitzka Main Spring. Flows from the spring are monitored by the United States Geological Survey (USGS). The discharge record begins in 1997 and stage begins in 1999. Spring discharge was estimated for periods preceding the initiation of USGS discharge measurement based on a regression equation developed for river flows and water levels in a Floridan Aquifer. The median flow of the Chassahowitzka River based on estimated and measured flows for the baseline period (1967-2007) used for determination of the minimum flows recommended in this report was 63 cubic feet per second (cfs).

There are currently no surface water withdrawals from the Chassahowitzka River currently permitted by the District. Groundwater withdrawals may, however, reduce discharge from the springs that contribute to the river's flow. A regional surface water/groundwater integrated model was used to determine that estimated water use in the region for 2005 resulted in a 0.7 cfs reduction in flows. For purposes of minimum flows development, this impact was considered insignificant and the evaluation proceeded without correction or modification of the reference period discharge record.

A variety of ecological resources of concern were identified and evaluated for response to reduced flows using both numeric models and empirical regressions. Resources of concern included submersed aquatic vegetation, benthic macroinvertebrates, molluscs, planktonic and nektonic fish and invertebrates, salinity-based habitat, and thermal refuge habitat for manatees during critically cold periods. Break-points in ecological response were not observed, and a fifteen percent loss of resource was adopted as representing significant harm.

The MFL recommendation is based on the resource most sensitive to reduced flow. Twenty-nine responses were evaluated, of which twenty-one were incorporated into development of the minimum flow for the Chassahowitzka River system. The two most restrictive components evaluated were the acute thermal refuge and the fish/invertebrate community. In both cases, an 11 percent reduction in baseline flow results in a 15 percent loss of volumetric thermal refuge for the West Indian manatee and a 15 percent loss of abundance (median value for seven taxa) of juvenile fish. Therefore, it is recommended that the minimum flow for the Chassahowitzka River system (including all contributing springs and associated creeks) be maintained at 89 percent of the baseline flow (see Table 8.2). In the absence of locally measured flows, the Chassahowitzka River System MFL shall also apply to Blind Springs.

The following table is also taken from the draft report:

Table 8-2¹⁰

Long term expected minimum flows corresponding to recommended MFL

¹⁰ *There are several typos in the District's Table 8-2. Reading from top to bottom the results should be 50.30, 49.85, 48.97 and 48.32 cfs)*

Criterion	Minimum Flow (cfs)
Minimum 10-Year Moving Average (based on annual average flows)	50.31 cfs
Minimum 10-Year Moving Average (based on annual median flows)	50.81 cfs
Minimum 5-Year Moving Average (based on annual average flows)	48.97 cfs
Minimum 5-Year Moving Average (based on annual median flows)	49.16 cfs

Comments and Recommendations

Overall, we find that the Southwest Florida Water Management District has done a commendable job of looking at the available data and collecting additional data where necessary. We also believe that the majority of the analysis is scientifically sound. We do, however, have concerns that some data might have been down-weighted for reasons that are not supported by the biology of the animals involved.

A healthy estuary represents a continuum from freshwater to marine. The proposed MFL for the Chassahowitzka River, however, appears to have the potential to adversely impact the freshwater fish community in this system. The modeling results for two freshwater fish species [blue fin killifish (*Lucania goodie*) and spotted sunfish (*Lepomis punctatus*)] retained in the assessment were largely discounted because responses were "very sensitive to flow changes" (paragraphs 3 and 4, p. 73 of 94). We request a further explanation of the reasoning used to discount these species, and a consideration to use these species to help define the MFL. Since these two species require freshwater habitats to recruit and for subsequent survival and reproduction, any inflow changes that reduce the available freshwater habitat would impact their abundance and distribution. Instead of being discounted as overly sensitive, the responses of these two species should be viewed as an indication that inflow reductions can reduce the available freshwater habitat and adversely impact the freshwater nekton community in this system. When flows are relatively high (≥ 65 cfs) individuals of these two species are relatively abundant in the main stem of the Chassahowitzka River. When flows are reduced to < 55 cfs, however, individuals of these species become much less abundant (MFL Appendices). Under these low flow conditions, these two species serve as early indicators that the freshwater nekton community most likely retreats to freshwater refugia at the headsprings from which they can re-populate to the main stem of the system when flow conditions increase. According to our analysis, the proposed MFL of approximately 50 cfs would limit these species to the headsprings at best.

Table 8-2 has been misinterpreted as representing the MFL. The District is not proposing a 50 cfs MFL, but rather the proposed MFL is maintenance of 89 percent of the baseline daily flow (11 percent of the daily flow may be withdrawn). The basis for the MFL is the most conservative reduction in flow that results in a loss of 15 percent of the habitat or resource. In the case of the Chassahowitzka MFL, the basis for selecting 11 percent is both the median fish/invertebrate response and the loss of acute thermal refuge for the manatee (See Table 8-1 in the draft report).

Development of the referenced table is described in section 8.2 of the report. The table represents the lowest 5-yr average flow that would be expected if 11 percent of the daily flow were removed from the 41-year record of flow. To put this in perspective, the lowest 5-yr moving average of the naturally occurring (baseline) flows in the absence of any proposed withdrawals is 55.0 cfs. Under the proposed MFL, this value would fall to 49.0 cfs but a five-year average flow this low has an expected return interval of approximately 38 years.

This section will be re-written and references to “compliance” will be eliminated.

Discounting the abundance-flow relationships for these two species is to risk extirpating them and similar species. Because the salinity characteristics of the river are expected to change as the suggested minimum flows are achieved, we believe it is important to use freshwater fish species (and perhaps these two in particular) to help determine these minimum flows

*This comment is in reference to the discussion contained in Section 7.1 of the peer review draft. This section and Table 7-1 will be re-written in the final report to correct a number of errors. First, the response for *F. grandis* was erroneously omitted from the final analysis. Second, the consultants (USF and FWC) treated flow data differently in developing their response regression. FWC added a one to the flow, while USF did not. In the initial draft that was circulated internal to the District, flow was erroneously transformed for both the plankton tow and the fish/invertebrate seine and trawl. The text and table contained in this section unfortunately reflects a mix of correct (seine and trawl) and incorrect (plankton tow) transformations of flow. The table that follows includes all taxa from Tables 5-5 and 5-6 that met the original criteria and were promoted to evaluation, and the sub-set selected for the MFL determination. Table 7-1 will be corrected in the final report.*

If all taxa identified in Tables 5-5 and 5-6 are retained, the resource median is 11.1 percent flow reduction, but for reasons described in the discussion beginning on paragraph 4 of page 73 and extending onto page 74, the District feels that the hypersensitive responses based on seasonal results should not be included in the establishment of a non-seasonal MFL determination (See response to FDEP comment 20). Excluding these taxa results in a median resource reduction of 11.5 percent. However, the recommended MFL will not be changed in the final report because the most conservative MFL is 11 percent for the acute thermal refuge for the manatees.

Taxa	Type of Regression	Flow Reduction (%)		
		As Presented in Peer Draft	All Taxa (corrected)	As Presented In Final Report
Plankton Net				
Anchoa mitchilli juveniles	Linear	1.0	2.6	2.6
Hargeria rapax	Linear	1.9	3.5	3.5
Dipterans, chironomid larvae	Linear	2.3	3.9	3.9
Seine and Trawl				
Farfantepenaeus duorarum (S)	Quadratic	17.2	17.2	17.2
Farfantepenaeus duorarum (T)	Quadratic	15.2	15.2	15.2
Fundulus grandis	Quadratic		11.9	11.9
Lucania parva	Quadratic	11.1	11.1	11.1
Lucania goodei	Linear		0.9	
Poecilia latipinna	Quadratic	13.3	13.3	13.3
Lepomis punctatus	Linear		1.6	
Lagodon rhomboides	Quadratic		17.9	
Median for resource		11.1	11.1	11.5

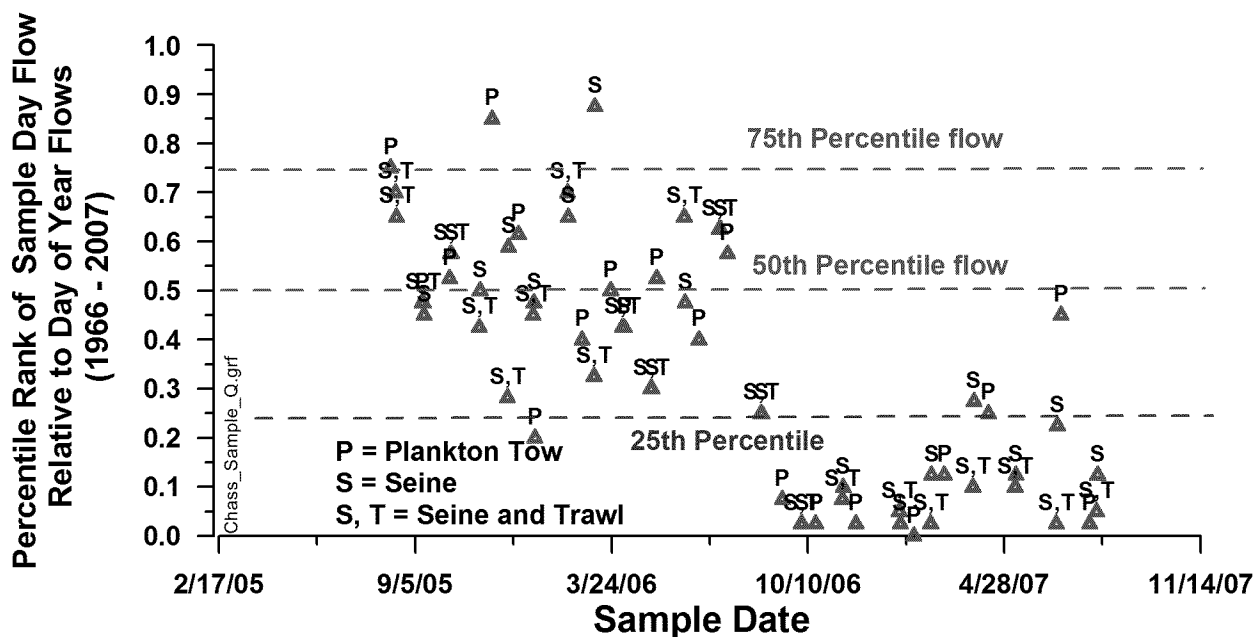
Section 5.2.1 describes a two-year study of freshwater inflow effects on habitat use by estuarine nekton that was conducted by the Fisheries-Independent Monitoring (FIM) program. Paragraph 1, p. 53 of 94 states that "These regressions can be applied to any proposed alterations of freshwater inflows that fall within the range of natural variation documented ... " The proposed MFL (~50 cfs) represents the 25th percentile of flows encountered during the FIM program sampling period. It is possible that the proposed MFL would shift the lower range of "natural variation" outside of the flow range that was sampled by the FIM program for some, if not all, of the assessed nekton species.

The District's evaluation was based on a 41-year period of record. The 2005-2007 – period sampled by FWC was a dry period representing the 62nd, 22nd and 12th annual percentile ranks respectively. The lowest 5-yr moving average (49.0 cfs) represents the 5-yr moving average for years 1993-1997 and represents an estimated return probability of 0.03 (e.g. rank 1 of 37 five-year periods evaluated.)

On p. 74 of 94, the following statement indicates" ... seasonally variable MFLs are not appropriate for this system." The monthly ranges used in the FIM program regressions match timeframes when each species was available to the FIM program's sampling gears. That does not imply, however, that a species is only present during the indicated months. During months outside of the indicated range, the animal is not efficiently captured by these gear types (i.e., size-specific escapement, ontogenetic habitat shifts, emigration, etc.) and the data cannot be used to assess their responses to inflow. Absence of a species from the FIM program's collections does not necessarily indicate absence from the system. Seasonally variable MFLs may not be appropriate, but it is important to maintain flow for the species that require it during each of their life-history stages.

This comment is not understood. Were the results sub-set into pre-selected periods and if so, what was the basis of the selection? The data presented

indicates that both seines and trawls were deployed throughout the calendar year. Sample dates reported for each are as follows (along with the percentile rank across 41 years for that day of year). If these taxa were simply not captured outside of the seasonal window reported, why wasn't a zero entered for the catch? If they were captured outside the May – November window, is there another regression reflecting the full data set?



The 15 percent loss of abundance criterion may not be the appropriate criterion to consider as causing ecological harm. The effect to species other than the presented species (such as freshwater species) needs to be considered as well. A 15 percent decrease in abundance for one species may be acceptable, especially for an abundant species; however, the extirpation of another set of species may be viewed quite differently.

The District acknowledges the comment and accepts the view. However, the legislature did not define 'significantly harmful' when promulgating the MFL statute and several peer review panels have commented on the District's use of 15 percent loss of habitat or resource. The majority of those comments have been supportive and it there does not appear to be primary literature supporting a quantitative acceptable value. For the past two years, the District has had an on-going contract Dr. Cichra at the University of Florida to identify peer-reviewed documentation identifying a threshold for 'significantly harmful' loss associated with flow reductions. In the absence of such literature, the District is developing a stream-diversion experiment to evaluate the effect of reduced stream flow. If a quantifiable and defensible definition of 'significantly harmful' is identified, the District will reconsider the currently applied 15 percent value during the next re-evaluation of the Chassahowitzka MFL.

The proposed MFL would decrease the amount of potential warm-water habitat that may currently be available at certain tidal and flow conditions to the West Indian manatee (*Trichechus manatus latirostris*). Warm-water habitat is considered the limiting factor for the manatee population in Florida. Warm-water habitat for manatees provided by natural spring systems is therefore critical to the recovery of this species into the future, and FWC therefore does not support a loss of warm-water habitat (FWC Florida Manatee Management Plan, 2007). For the purposes of establish an MFL for the Chassahowitzka, however, this is not likely to become an issue since the Chassahowitzka River is used primarily as warm-season habitat and the possible loss of a small portion of the marginal warm-water habitat that may be periodically available should not have a significant effect upon the survival of the West Indian manatee.

Comment noted.

We have enclosed additional comments from our staff for your consideration and for revision of the Chassahowitzka River MFL document. We believe that the proposed MFL is too low and would shift flows to the lower range of "natural variation", which risks extirpating certain freshwater species from the system. In this case, we believe that the more sensitive species would be sound indicators for assessing and monitoring the effects of a proposed MFL. In systems that have developed under a relatively constant inflow, we'd suggest that MFLs fault on the side of being overly conservative.

As discussed with your staff, if you or your staff would like to coordinate further on the recommendations contained in this report, please contact Mr. Theodore Hoehn 850-488-3831 or email at ted.hoehn@myFWC.com.

Sincerely,

Mary Ann Poole
Commenting Program Administrator

Additional FWC comments:

- "much of the Chassahowitzka estuary exists in the unconfined broad shelf beyond Rkm=0 ... " (Paragraph 3, pg. 40 of 94) is not supported by data presented here and is likely not an accurate statement. We do not know how much of the area outside of Rkm zero is actually impacted by the flow from the Chassahowitzka. It seems reasonable that this river's small freshwater signature quickly dissipates in the greater Gulf of Mexico outside of RkmO. We believe that the bulk of the Chassahowitzka estuary is actually contained within the extensive salt marshes and tidal creeks that extend north and south from the river starting at approximately Rkm 5. Of these areas, we know very little.

Comment noted. In the context of the statement, the District was simply acknowledging that additional mixing continues beyond Rkm 0 and that the Chassahowitzka contributes freshwater to that area. In that context, it is an extension of the Chassahowitzka estuary. The District considered extending the boundary, but the area beyond Rkm 0 is admittedly affected by flows from other sources as well (See Dixon and Estevez (2001) for additional discussion about

the near-coastal areas beyond Rkm 0). The statement will be edited in the final report.

- The flow rates used in the salinity profiles plots (4-3) on pgs. 42 and 43 of 94 seem very high for this system (71 to 150 cfs). Fisheries Independent Monitoring (FIM) program staff sampled this system from August 2005 thru July 2007. The median flow during this period was 61.7 cfs with a range from 25 to 87 cfs. What flows were used in these plots and why are they so high?

As identified in the figure captions, the salinity profile plots were adapted from plots originally presented in USGS WRI 88-4044 (See Figure 8 in Yobbi and Knochenmus, 1989) and represent flows measured during the 1984-86 study. The USGS reports that the discharge records were produced from a relationship between discharge and groundwater levels (see page 6 of Yobbi and Knochenmus, 1989).

Prior to 1997, flow for USGS station 02310650 included the contribution from Main Spring, Chassahowitzka #1, Chassahowitzka #2 and Crab Creek, while post-1997 discharge reported for this site does not include Crab Creek (D.Yobbi, personal communication). A statement to this effect will be added to the final report.

- Referring to same plots as above, at 71 cfs a salinity of 3 ppt is found almost at Rkm 7. This leaves very little room for oligohaline and freshwater zones before the springhead at Rkm 9.

Comment noted.

See USGS quote that follows.

"In this report, a salinity of 3 ppt is used to establish the upstream extent of the zone of freshwater mixing in the Chassahowitzka, . . . These concentrations were selected because they are only slightly higher than the background salinity of the inflowing water from each river . . . (Yobbi and Knochenmus, 1989. Page 3)"

- "very slightly alkaline" (paragraph 2, pg. 46 of 94). Very and slightly would seem to nullify each other. Was something else intended, such as "are slightly alkaline" or "are very alkaline"?

The intent was to indicate that the pH was greater than 7.0 but only by a small amount. In this usage, the word 'very' means 'comparatively'.

- Robust regression (paragraph 1, pg. 59 of 94). As written, this technique appears to have been only applied to the seine and trawl data. However, staff believes, based upon later text, that it was also applied to the plankton data as well. Clarification of this point should be considered. If it was not applied to the plankton data, some explanation as to why would be appropriate.

The decision to apply robust regressions was made primarily to determine if the quadratic equations used only with the seine and trawl data by FWC were influenced by high leverage points or outliers. In the case of the original Chassahowitzka evaluation of the results (Greenwood et. al. 2008), 61 percent of the best-fit significant flow/abundance responses were reported as quadratic responses.

- " ... strongest positive abundance/flow responses ... " (Section 6.1.2, pg. 70 of 94): Staff is uncertain that "strongest" is the correct word here. There were regressions with a better fit (adjusted r²) that were discarded because of the robust regression results.

Final report will be edited to reflect that fact that these were the strongest relationships meeting all of the criteria.

- Table 8-2 (pg. 83 of 94): each of the proposed MFLs is centered around 50 cfs. During the FIM program's study of this system, the 25th percentile of flow was 50 cfs.

Comment noted. See prior explanation.

Citations:

Dixon, L.K. and E.D. Estevez, 2001. Summary of information: water quality and submerged aquatic vegetation in the Chassahowitzka National Wildlife Refuge 1996-2001. Mote Marine Laboratory Technical Report Number 759. Prepared for U.S. Fish and Wildlife Service July 6 2001. Denver, Colorado.

Greenwood, M.F.D., E.B. Peebles, S.E. Burghart, T.C. MacDonald, R.E. Matheson, Jr., and R.H. McMichael, Jr. 2008. Freshwater inflow effects on the fishes and invertebrates in the Chassahowitzka River and estuary. University of South Florida and Florida Fish and Wildlife Conservation Commission. St. Petersburg, Florida. Prepared for Southwest Florida Water Management District. Brooksville, Florida.

Yobbi, D and L.A. Knochenmus, 1989. Salinity and Flow Relationships and Effects of Reduced Flow in the Chassahowitzka River and Homosassa River Estuaries, Southwest Florida. USGS Water Resources Investigation Report 88-4044.

11.3 Review Comments from Florida Department of Environmental Protection and District Response.

DEP Comments Chassahowitzka River MFL (April 2010 Draft)

1. Page 11, line 2 – From the description, it is not clear where Spring #1 is. It is 350' upstream of what? Similarly, in line 5, the main spring is 200' NE of SR 480, but it is not clear where this road is located. A reference to Figure 2-4 could be helpful here, except that the spring names in Figure 2-4 are mostly illegible. We recommend using a map the size of Figure 3-8, page 36, instead of the current Figure 2-4.

The designation of the road will be corrected to read county road instead of state road. CR 480 dead-ends at a boat ramp located at the Citrus County Chassahowitzka River Campground. The Main spring is located approximately 200' NE of the ramp. A short (150') creek enters on the north side of the river 150' upstream of the Main spring. Chassahowitzka #1 and Chassahowitzka #2 are located at the headwaters of this creek. Figure 2-4 will be expanded to match the size of Figure 3-8.

2. Page 12, Section 2.1.1, paragraph 1, midway down – The references to Crawford Creek and Dog Island would be helped by a reference to the river kilometers shown in Figure 3-8. Also, note the typos in the parentheses "...Crawford Creek (R km 3.5. See)..." A reference will be included in the final report.

Paragraph 2 – The text references Figure 2-5, yet Figures 2-3 and 2-4 have not been introduced at this point. Also, the second sentence mentions development when it references Figure 2-5, but Figure 2-5 is a graph of river discharge, not urbanization. The reference will be corrected to read Figure 2-4.

3. Pages x and 18 cite that historic flows were determined by a regression equation developed for river flows with water levels from a Floridian Aquifer well. (Note the missing word "well" on p. x.) It would seem more appropriate for a regression equation for estimating historic flows be based upon rainfall, Floridian Aquifer levels, and spring discharges as the report cites that spring discharges are the overwhelming contribution to the rivers flow volume. Or, that such a comparison be done for the period of record for field measures. *Flow in the Chassahowitzka is dominated by spring flow arising from the Floridan aquifer with very little surface runoff. The USGS has developed discharge relationships from water level in the Floridan aquifer for many of the rivers in the springs coast. (See Table 1 in USGS Water Resources Investigation Report 01-4230). Many of these relationships have coefficients of determination in excess 0.8 indicating that the majority of discharge can be accounted for without including the surface runoff. For many years, the USGS has estimated the discharge of springs in this area using relationships to Floridan aquifer levels. The*

approach used to hind cast flows for the Chassahowitzka are based on an approach similar to the USGS. Daily discharge reported by the USGS for site 02310650 was paired with daily water levels reported for the Weeki Wachee Well (283201082315601) and a linear regression developed. ($r^2 = 0.75$, $n = 3260$). This regression was then used to hind cast discharge back to the beginning of the Weeki Wachee Well record.

4. The evaluation was based on the discharge data from the uppermost USGS station, just downstream of Chassahowitzka Main spring. Although this approach may be the simplest by eliminating tidal influence to the greatest extent possible, it also means that the other tributary springs' contributions are not considered. We recommend that all data available from these other spring systems be used in the model to the extent practicable. *To clarify, in addition to the discharge from Chassahowitzka #1 and #2, and the Main spring, the hydrodynamic modeling included mean discharge and salinity measurements for Crab Creek, Potter Creek, Baird spring, Blue Run and Bettejay head spring entering the model at appropriate model cells. The hydrodynamic model was used to establish allowable flow reductions for shoreline, bottom area, salinity volume and thermal habitat. The salinity regression model included discharges only from Chassahowitzka #1 and #2, and the Main spring and was used to assess benthos, mollusc, SAV, and fish/invertebrate response to reduced flows.*

For example, in calculating the overall median flow of 63 cfs, the discharge from Crab Creek Spring was eliminated from the analysis. Crab Creek Spring appears also to be a headwater and to contribute about 33% of the flow, making it a significant water source (see Figure 3-8, p. 36, and the Crab Creek flow information, pp. 11, 12, and 18). Along with Chass Main and Chass #1, the three springs cumulatively contribute about 83% of the flow, indicating the 63 cfs used in the MFL analysis is too low. We do not know from the report how many discharge measurements exist for this spring and when they were taken (see p. 19, Figure 2-5). Is this information available? If needed, could discharge for this spring be estimated using the Weeki Wachee well? *Sufficient discharge measurements have been made at Crab Creek, and an 'unnamed' tributary to develop a regression and the USGS has done so (See WRI 01-4230). However, the USGS does not report daily flow for either of these sites. If the MFL were established based on discharge from an unreported source, compliance would be more difficult to assess. The District acknowledges that true total flow in the Chassahowitzka is unknown, but in accordance with FS 373.042, the MFL was based on the "best information available".*

Similarly, the Bettejay group of springs may be an important source of fresh water of the system. We noticed that observations for this spring group exist from 1961-1964, before the reference period chosen for the analyses. Section 2.3.2 (p. 20) does not provide the rationale for selecting this time particular reference period. Could the District expand the reference period in order to use more of the available data? *The reference period represents the historical limit of water level measurements in*

the Weeki Wachee Well, which is the basis for estimating discharge in the Chassahowitzka River.

Moreover, flow data from Rossenau et al. 1977, covering 1930 to 1972 and including some 81 measurements, show that the average discharge for the Chassahowitzka River just below Crab Creek was 138.5 cfs—significantly higher than the current 63 cfs median calculated in the report. This large difference suggests that either these measurements are in error, important springs amounts have been eliminated from the analyses, or there have been significant declines in flow. If this change were from declining flows, it seems that the Chassahowitzka River has already been impacted and any further reduction in flow could exacerbate an existing problem. Declining flows also indicate further investigation of possible anthropogenic influences from area groundwater withdrawals or other causes might be necessary. *Presently, discharge reported by the USGS for station 02310650 includes flow from Chassahowitzka #1, Chassahowitzka #2, and the Mainspring. Flow from Crab Creek is not presently included, although it was included in discharge measurements reported for this station prior to 1997 (D. Yobbi, personal communication. This information became known after the draft report was released, and a caution will be added to the final report.) The District did not use any USGS reported discharge from this station prior to 1997, but comparing flows in the older USGS reports should be done cautiously. Since the regression developed by the District is based on post-1997 discharge (which does not include Crab Creek), estimate of pre-1997 flows from that regression does not include contribution from Crab Creek either.*

The District acknowledges a statistically significant decline in flows (See Section 2.4, but the District believes that the decline is the result of climate change and is unrelated to anthropogenic activities. Modeling of current withdrawals within 14 miles of Chassahowitzka projects less than 1 cfs decline due to groundwater pumpage and there are no surface water withdrawals from the river.

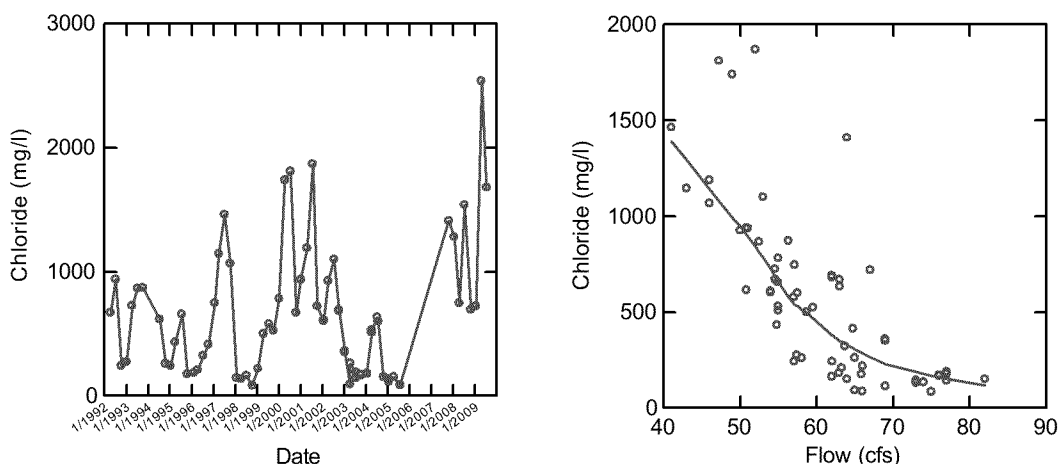
5. Pages 19-20, Table 2-4, Figures 2-5 and 2-6 – Which springs are included in these tables/graphs? *Chassahowitzka #1, #2, and Main spring.*
6. Page 21, Table 2-5 – Is the information for Chassahowitzka Spring referring to Chass Main, Chass #1, or both? *According to the author of the USGS report, discharge measurements prior to 1997 included the Chassahowitzka #1, #2, Main spring and Crab Creek.*

Last paragraph (italicized) – It is unclear where “the USGS site” being discussed is located. In the paragraph above, which USGS gauges are considered “long-term?” Without this information, the argument is hard to follow. *See Figure 2-7 and appendix 3 for the original report and a location map. The “long-term” gage refers to 0231065. Clarifying language will be added to the final report.*

(There also are typos in the next to last sentence of paragraph 1.)

7. Page 24, Figure 3-1 – The major springs in this system are found within the freshwater wetland forested areas of the basin boundary as defined in this document. (There may also be many currently undocumented seepages throughout the tidal marsh systems, particularly at the heads of tidal creeks). The draft document includes a discussion of this riparian habitat, both at this system and in minimum flow determination for other rivers, and Figure 3-8 depicts the marsh-forest demarcation line, yet plant communities were not included in resources of concern. The salinity habitat criteria was considered to be “a surrogate” for many of the riverine functions, but it is not clear that this would be protective of the most restrictive, freshwater habitats in the river system that are contiguous with and reflective of the springs and the spring runs. *Comment noted. The District believes that maintaining the same salinity in the future as exists now for 85 percent of the shoreline, volume and bottom habitat is an appropriate management approach for establishing an MFL. Within the 85 percent of this habitat that remains unchanged, it is unclear how a freshwater habitat would not be protected by this approach.*
8. Page 33, last paragraph – Although Chassahowitzka was part of the multi-river study by Clewell, et al (2002), the quoted conclusion that “breaks in vegetation...are not reliable as predictors of specific salinity regimes” summarizes finding of both spring-fed systems and surface-water driven systems. This conclusion may not be as applicable to this system, which is characterized by little seasonal variations in spring flow, resulting in more stable ecological communities. Furthermore, most of the Clewell et al. sampling stations along the Chassahowitzka were within marsh systems, and not within the forested systems. *Comment noted. The District quantified (See Table 7-4) the length of shoreline above the 2, 5, 10, and 15 ppt isohaline at median flow conditions.*
9. Page 41, paragraph 2 – The text refers to two studies, but the preceding paragraph mentions three studies. *The unpublished data is an addendum to the Dixon and Estevez study reflecting newer data collected subsequent to the 2001 publication. Effectively it is one continuing data collection with the early data summarized in the published report.* Also, it is unclear if longitudinal (title of the section) or vertical (subject of the preceding paragraph) salinity is being discussed, why these discussions are not in the appropriate subsections that follow (i.e., longitudinal and vertical salinity), and what parameters are being correlated. Should the title of Section 4.2 (page 39) simply be “Salinity”? *The material presented on pages 39 through 41 describe longitudinal salinity variation. The sub-heading 4.2.1 will be eliminated to clarify this point. The text beginning on page 42 is intended to illustrate the vertical salinity variation as a function of flow and location. The Chassahowitzka is a well mixed system as illustrated by the fact that in most combinations of tide and flow, there is little to no difference between the surface salinity and the salinity at the bottom. Plates C and D illustrate that at low flow and high salinity, some displacement occurs. For example, the location of the 15 ppt surface isohaline is displaced seaward from the location of the 15 ppt bottom isohaline.*

10. Florida Geological Survey Bulletin 69 shows that spring water is becoming increasingly saline. If this is the case in the Chassahowitzka River, then additional reductions in flow may seriously affect the salinity of the system since the majority of flow in the river comes from groundwater discharge through springs. *Comment noted. The basis of the District's MFL is to determine the amount of flow reduction that will result in significant harm. All of the major springs in this complex have exhibited changes in salinity and chemistry over the years. The figure below illustrates the variation in chloride through time (left panel) and by flow (right panel) in flow from Chassahowitzka Main for the period 1992 - 2007. Clearly, the variation in chloride concentration is a function of flow, but the District's groundwater modeling indicates that change in flow resulting from groundwater withdrawals is approximately 0.7 cfs. The premise of the District's MFL evaluation is that significant harm will occur when withdrawals cause an 11 percent decline in habitat or resource.*



11. There is a possible connection between algal abundance and flow. Photographs taken in early June of this year by DEP staff show the Chassahowitzka River already experiences algal problems. What would be the impact on the system of further reductions in flow? *The response could take several forms and be either negative or positive depending on how the abundance is related to flow. For example, if macro- algae is drift or attached to the substratum and flow is a significant nutrient source (as is the case of elevated nitrates.), then one might expect a reduction in flow to result in a reduction in algae. On the other hand, if micro-algae are suspended in the water column, a reduction in flow will increase residence time, potentially allowing bloom conditions to form within the river.*
12. In establishing ecological criteria to be evaluated, i.e., "resources of concern," an evaluation of palustrine wetlands via a change assessment would provide a valuable landscape indicator. *Comment noted. The District evaluated the available Chassahowitzka aerial coverages and associated land use codes in an*

attempt to perform a change analysis related to tree die-off. The District found that resolution was lacking. Yet, even if the resolution existed, it was unclear to District staff how to remove the other environmental stresses that are unrelated to flow reductions in order to establish a quantifiable flow-based response. For example, Dixon and Estevez (2001) documented the effect on the SAV community when a single day, high-stage event flooded much of the river system with saline Gulf water. This change in community structure was unrelated to flow or withdrawals and had it not been documented, interpreting the SAV results in terms of flow alone would be difficult at best. In terms of the palustrine wetland, it should be noted that the Chassahowitzka River is tidal above the Main spring and bottom salinity at the Main spring presently (August 1-2, 2010) has a daily range from 0.9 to 4.2 ppt.

13. The basis of establishing 15% of natural resource loss, as being the measure of impairment, would be well served by first defining the resources, the components of ecosystems, and system functions all within a single system context. This would allow the impact due to loss of a given species to be related to the whole system as well as related to economic values, ecological economic values, etc. *Comment noted.*
14. One potential means of assessing and evaluating the dynamics needed to maintain a system, riverine system, would be to perform a change analysis using a variety of landscape scale measures. This could be accomplished by utilizing differing satellite platforms offering visible, near infrared, to microwave platforms that can measure plant health, cover types, even water levels and soil saturation. These dynamic measures may be correlated to measured rainfall, flow, spring discharge, and changes within a watershed such as land development and land conversions. Thus, the dynamics of a river system might be captured both in response to natural events such as rainfall, but also captured against what may be significant anthropogenic influences, impacts, such as land cover change, with its associated impacts such as stormwater runoff. *Comment noted. See limitations noted in response to point number 12.*
15. The MFL also might be evaluated by consideration of potential critical refugia and impacts of conductivity to species, especially larval forms. *Comment noted. The MFL does include an evaluation of the thermal refuge provided by the Chassahowitzka system for the West Indian Manatee and larval forms were captured and evaluated as part of the fish/invertebrate response to reduction in flow.*
16. Consideration should be made for evaluating, external to model results, extreme conditions of drought which may dramatically reduce flow from the spring system, and establish a natural baseline as to minimum flow for ecological resiliency of the system. *Comment noted.*
17. *Vallisneria americana* is a known food source for the West Indian Manatee. If densities are affected by flow reduction in the Chassahowitzka River system, how will that affect the manatee especially when utilized during the critical cold weather

periods? *The relationship between warm refuge and forage response appears to remain open for debate. For a brief literature review, see the Florida Fish and Wildlife Conservation Commission discussion at http://myfwc.com/wildlifehabitats/manatee_habitat_foraging.htm. In order to make the linkage suggested by the reviewer, a defensible and quantifiable relationship between reduced flow and *V. americana* density would be required. A separate quantifiable demonstration that the loss of *V. americana* in the Chassahowitzka constitutes a 'significant harm' to the West Indian Manatee would also be required. The District has attempted on several occasions (e.g. Chassahowitzka MFL and Weeki Wachee MFL) to quantify the effects of reduced flow on SAV and seagrass without success. (See section 7.2). Furthermore, there is evidence that manatees have nutrient preferences that can influence foraging patterns during the winter. Rathburn et al. (1990)¹¹ states "...as a result of our radio-tracking studies, we learned that manatees in both the Homosassa and Crystal Rivers frequently left the warm headwaters during the coldest months to feed on *Ruppia maritima* and *Potamogeton pectinatus* downriver, despite the abundance of other plants near or in the warm water" (cited in Warm-Water Task Force, 2004¹²). Such behavior is unrelated to reduced flows, and would complicate the relationship(s) needed to make this a quantifiable MFL metric.*

Manatee survey results obtained from U.S. Fish and Wildlife Service indicate that the Chassahowitzka is used more often during warmer months than during the cold months. This is probably the result of the fact that warm water of sufficient depth is largely absent during the colder months. Through 2006, there were no recorded aerial surveys on the Chassahowitzka River for the months of September through December. For the months of January through May, the average number of animals sighted are 0.1(Jan), 1.2 (Feb), 13.5(Mar), 8.0 (Apr) and 24 (May).

18. Page 73, paragraphs 3 and 4 – The reduced flows and percents for plankton presented in paragraph 3 are different from the values shown in Table 7-1. Data for the seine and trawl species mentioned in paragraph 4 also are not found in the referenced Table 7-1. *This section and Table 7-1 will be re-written in the final report to correct a number of errors. First, the response for *F. grandis* was erroneously omitted from the final analysis. Second, the consultants (USF and FWC) treated flow data differently in developing their response regression. FWC added a one to the flow, while USF did not. In the initial draft that was circulated internal to the District, flow was erroneously transformed for both the plankton tow and the fish/invertebrate seine and trawl. The text and table contained in this section unfortunately reflects a mix of correct*

¹¹ Rathbun, G. B., J. P. Reid, and G. Carowan. 1990, Distribution and movement patterns of manatees (*Trichechus manatus*) in northwestern peninsular Florida. Florida Marine Research Institute Publication Number 48: 1-33.

¹² Draft Recommendations For Future Manatee Warm-Water Habitat. Warm Water Task Force. December 27, 2004.

(seine and trawl) and incorrect (plankton tow) transformations of flow. The table that follows includes all taxa from Tables 5-5 and 5-6 that met the original criteria and were promoted to evaluation, and the sub-set selected for the MFL determination. Table 7-1 will be corrected in the final report.

If all taxa identified in Tables 5-5 and 5-6 are retained, the resource median is 11.1 percent flow reduction, but for reasons described in the discussion beginning on paragraph 4 of page 73 and extending onto page 74, the District feels that the hypersensitive responses based on seasonal results should not be included in the establishment of a non-seasonal MFL determination (See response to FDEP comment 20). Excluding these taxa results in a median resource reduction of 11.5 percent. However, the recommended MFL will not be changed in the final report because the most conservative MFL is an 11 percent flow reduction associated with the acute thermal refuge for the manatees.

Taxa	Type of Regression	Flow Reduction (%)		
		As Presented in Peer Draft	All Taxa (corrected)	As Presented In Final Report
Plankton Net				
Anchoa mitchilli juveniles	Linear	1.0	2.6	2.6
Hargeria rapax	Linear	1.9	3.5	3.5
Dipterans, chironomid larvae	Linear	2.3	3.9	3.9
Seine and Trawl				
Farfantepenaeus duorarum (S)	Quadratic	17.2	17.2	17.2
Farfantepenaeus duorarum (T)	Quadratic	15.2	15.2	15.2
Fundulus grandis	Quadratic		11.9	11.9
Lucania parva	Quadratic	11.1	11.1	11.1
Lucania goodei	Linear		0.9	
Poecilia latipinna	Quadratic	13.3	13.3	13.3
Lepomis punctatus	Linear		1.6	
Lagodon rhomboides	Quadratic		17.9	
Median for resource		11.1	11.1	11.5

19. Page 74, partial paragraph – If seasonal flow variation is minimal, and data exist for *L. goodie* and *L. punctatus* during the low flow and high flow months (May – July and September – November, respectively; see page 18), why are these “hypersensitive” species eliminated from the analysis? What criteria define “hypersensitivity?” Eliminating these species eliminates all linear response species. *All of the plankton tow results are linear responses and are provided as the top three taxa on Table 7-1 under the heading “Plankton Net”. One of the taxa eliminated from further evaluation was a quadratic response and two were linear responses. See Table 5-5 and 5-6 for coefficients.* What happens if you make assumptions allowing the inclusion of these two linear response species in the analysis? (See prior response) Are the remaining species as sensitive to flow as the three eliminated species? *The response of each taxa is given in the last column of*

Table 7-1. Table 7-1 will be revised in the final report to document the reductions of all taxa.

*The District's main concern with including these two taxa in the MFL determination is the reasonableness of any response curve that is ultra-sensitive to changes in flow. Using the response regression for *L. goodie* indicates that a reduction of 0.9 percent in flow will result in the loss of 15 percent of the organisms. Extending the application of the regression, if the 175-day average flow (representing the flow lag term in the regression) is reduced 8 cfs (from 63 cfs to 55 cfs), the regression predicts that ninety-five percent (see Figure 7-1) of this taxa will be eliminated from the system. To put this in perspective, in the absence of any withdrawals, historically this taxa would have been extirpated from the river 2,156 times between 1967 and 2007. A similar evaluation of *L. punctatis* results in extirpation 1,513 times over the same period. It seems unreasonable that killifish are eliminated so easily and so frequently from this system.*

The District arguably should have eliminated several other taxa from consideration, but results for the taxa that were eliminated were based on a seasonal subset of the sampling data that does not reflect annual response. In order to partially address these concerns, the District used the median of the individual fish and invertebrate responses in lieu of selecting the most conservative taxa.

There are a number of potential explanations for this apparent aberration. It may be that the flow domain of the collection period was insufficient, or that the spatial sampling domain is not representative for freshwater taxa. Nevertheless, the District questions whether such sensitive response regressions are representative or reasonable.

*It should also be noted that fish/invertebrates were not the only resource exhibiting hypersensitivity to flow reduction. Similar issues were encountered when attempting to relate SAV density to flow. Flow reductions less than 2 percent were predicted to result in loss of 15 percent of the SAV density. These flow reductions result in predicted salinity change of approximately 0.2 ppt for *Vallisneria americana* which has a reported salinity tolerance from 0 to 9 ppt.*

*Last paragraph – The data for *F. duorarum* presented in the text do not match the values shown in Table 7-1. This will be corrected in the final report. Also, the last sentence's reference to Figure 7-1 seems odd since this graph is for an eliminated species. Corrected*

20. *If salinity is a major factor in environmental change in this system, the impact of rising sea-level and climate change on the Chassahowitzka River system should be addressed. The District acknowledges that changes in sea-level will change the salinity regime throughout the system, but it not obvious how to estimate*

and incorporate the rise into the present MFL especially in light of the widely varying estimates of the rate. The District is committed to re-evaluating the MFLs periodically. When the re-evaluation is undertaken, it is anticipated that new salinity data will be collected, and related to flow through new regression and modeling efforts at the time of re-evaluation.

21. Pages 77-78 – It would be helpful to have a discussion of the results presented in Table 7-4. *Table 7-4 lists the reduction in flow that will cause a 15 percent reduction in either volume, area or wetted shoreline for a specified maximum salinity. The discussion is contained in the last paragraph on page 77. For example, if flow is reduced 22 percent there will be loss of 85 percent of the water (volume) that is at, or below 2 ppt salinity.*

22. Page 78, paragraph 1 – What does “worst case” mean? Is it simply January 4-7, 2007, or does Figure 7-2 also consider high tides? *The reference to section 6.1.5 on page 78 is incorrect and should read section 6.1.6. The “worst case” scenario is based on a joint probability of conditions during the Manatee season (October to March) and consists of cold water, low discharge of warm water and high tide to maximize the intrusion of cold Gulf Water. A return interval of 50 years was chosen to represent the average life expectancy of the manatee. During the period chosen, the minimum temperature ranged from 13.5 to 15.0 oC, discharge 48-48 cfs and stage from 0.3 to 1.7 ft.*

 Paragraph 2 – What are the “acute conditions” and when does this suitable habitat occur? (Also, correct the typo “or” in the last sentence.) *“Acute” and “chronic” conditions are defined in section 6.1.6. Chronic refers to three consecutive days of critically cold conditions, while acute refers to four consecutive hours of critically cold conditions.*

23. The analysis should quantify any degradation that has occurred in the Chassahowitzka River system, as significant harm may have taken place already. (The river is currently being considered for listing as impaired by DEP’s TMDL section.) Historical aerial photography would provide an insight into how the Chassahowitzka River ecology has changed over time and may provide insight into how much the system has already been impacted. *Under the MFL statute, ‘significant harm’ is evaluated solely within the context of withdrawals. There are no surface water withdrawals on the River and the impact due to groundwater withdrawals has been shown to be insignificant (e.g. 0.7 cfs). The District acknowledges that nutrients (namely nitrate) are increasing, but the increase appears to be independent of flow (see discussion in Section 4.3). This type of water quality degradation and the regulation thereof is not within the District’s authority under the MFL statute*

24. Page 80, last paragraph – What is the justification for using a median value to determine the MFL, instead of using the most sensitive species, as in previous reports? This methodology conflicts with the earlier statement (page x, last paragraph) that “[t]he MFL recommendation is based on the resource most sensitive

to reduced flow.” The statement (page 80) “... it was determined that the median... should be used” is too vague. How was this determination made? A discussion of the reasoning behind this decision is needed. *In the present application, several of the fish/invertebrate taxa exhibited apparent sensitivity to flow reductions that simply do not seem reasonable for estuarine taxa. There are four estuarine taxa that are reported to decline 15 percent with flow reductions less than 2.5 percent. To put this in perspective, a 2.5 percent flow reduction is expected to cause a 0.4 ppt increase in salinity at the mouth of the river (Rkm =0) and an equivalent increase at a location one-half the distance to the Main spring. Salinity at the Main spring presently (August 1-2, 2010) ranges from 0.9 to 4.2 ppt.*

Again, regarding the “hypersensitive” characterization, it seems the *A. mitchilli* results indeed could be an ecological response, and the conservative (protective) approach would be to choose the flow that does not cause significant harm to this species. What do the models show would happen to the populations of each of the three “sensitive” fish/invertebrate species eliminated from the analysis if flows were reduced by 11% instead of 1-2%? *See Figure 7-1 and response to comment 19. If flow were reduced by 11 percent, according to the robust regression the abundance of L. punctatus would decline by 78 percent.*

25. Page 81, Table 8-1 – The resulting MFL summary shows a 15% loss of volume, area, and shoreline in the 5 ppt habitat at 13, 15, and 13% flow reduction, respectively. Given that the proposed MFL is for 11% reduction, the freshwater and low salinity systems may not be sufficiently protected by this proposal. This potential habitat impact has not been directly addressed by this document. *This comment is not understood, as allowing an 11 percent reduction in flow would be more protective of the 5 ppt habitat than allowing a 13 percent or 15 percent reduction in flow. More 5 ppt habitat will exist at an 11 percent reduction than at a 15 percent reduction.*
26. Page 82, paragraph 1 – The report recommends maintaining the Chassahowitzka River flow at 89% of baseflow and that this MFL be applied to associated creeks and springs, including Blind Spring. It is not clear, however, that these systems will be monitored – collectively or individually – and in comparison to which baseflow, given that only one USGS station was used in the development of the MFL. The means of monitoring to determine compliance with the MFL should be explained. *All of the springs and associated creeks exhibit tidal fluctuations making direct monitoring of discharge expensive and problematic. The lack of individual, long-term discharge measurements at the creeks and springs prohibits setting individual MFLs for these systems. As a result, the MFL derived for the Main spring will be used as a surrogate for the entire system. The USGS reported discharge for station 02310650 (reporting collective discharge from Main, #1 and #2) will be used to assess compliance in accordance with the long-term expected flow statistics presented in Table 8 -2.*
27. Given that the surface water basin for the Chassahowitzka River System is different from the spring recharge basin (or springshed), which of these basins will be used in

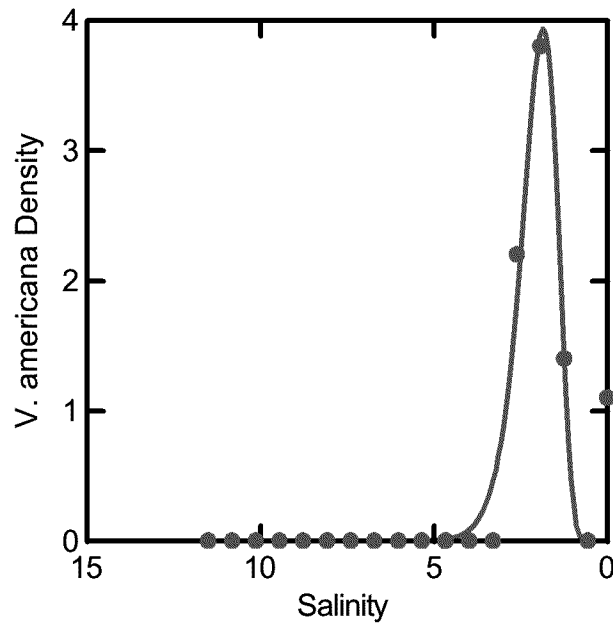
determining if water use permitting will be in compliance with the MFL? The document is silent on this matter. It is recommended that both basins be used. *Withdrawals from the groundwater basin or direct surface water withdrawals will be subject to the MFL rule.*

28. Several references need correction: *Will be corrected in the final report.*

- a. Page 15, last line – Table 2-6 does not exist.
- b. Page 23, section 3.1.2, paragraph 2, last line – The reference should be to Table 3-1.
- c. Page 33, paragraph 2, last line – Table 3-4 does not exist.
- d. Page 41, top line – The reference is to Section 4.2.1 (longitudinal salinity variability), yet the sentence discusses vertical mixing.
- e. Page 76, paragraph 1 – Figure 5-4 is about manatees, not SAV. There does not appear to be a figure corresponding to the discussion presented in the text. Also, in paragraph 3, should the Rkm cited be 6 instead of 7 (see Table 7-3)? *Corrected. The table will be modified to identify the Rkm of maximum density.*

As an aside, after the draft report was distributed, the SAV was re-evaluated using the optimal salinity regression form identified for evaluation of mollusc. This form has the advantage of identifying peak, or optimal salinity and the results confirmed the results reported in the draft report.

The results for V.americana follow. This regression exhibits an r^2 of 0.92 ($n=17$). When this expression is coupled with the salinity/flow model, an increase of 0.76 ppt salinity is predicted to reduce the density by 15 percent compared to a 0.20 ppt increase predicted by the polynomial regression described in the report.



Optimization model of *V. americana* density as function of salinity.

29. It would be helpful if the appendices were broken down into separate documents instead of one large .pdf file. *Suggestion noted. Individual documents will be made available on the District's web site.*

**Comments received after September 30 2010
and District response will be issued as revision 01.**